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High Development and Fertility: Fertility at Older Reproductive Ages and Gender Equality Explain the Positive Link

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Keywords

Fertility and development, Gender equality, Low fertility

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High development and fertility: fertility at older reproductive ages and gender equality explain the positive link

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Abstract

A fundamental switch in the fertility—development relationship has occurred so that among highly developed countries, further socioeconomic development may reverse the declining fertility trend. Here we shed light on the mechanisms underlying this reversal by analyzing the links between development and age and cohort patterns of fertility, as well as the role of gender equality. Using data from 1975 to 2008 for over 100 countries, we show that the reversal exists both in a period and a cohort perspective and is mainly driven by increasing older reproductive-age fertility. We also show that the positive impact of development on fertility in high-development countries is conditional on gender equality: countries ranking high in development as measured by health, income, and education but low in gender equality continue to experience declining fertility. Our findings suggest that gender equality is crucial for countries wishing to reap the fertility dividend of high development.

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INTRODUCTION

Very low fertility that is substantially below replacement level is one of the key demographic and policy challenges in high-development societies. Low and sometimes very low fertility has already spread to some middle-income countries, and sustained periods of low fertility are projected for many countries even if their fertility currently is still above or near replacement levels (United Nations Population Division 2011). For example, South America and Asia currently have above replacement fertility, but according to the UN medium projection they drop below replacement in the next ten years and stay there at least until 2050. In one speculative extrapolation of current trends, Wilson (2011:382) even states that “Over a somewhat longer time frame, we cannot exclude the possibility of a reversed differential, with higher fertility in the rich world than in the poor”. Already since late 2003 or early 2004 the majority of the world population lives in areas with below-replacement fertility (Morgan and Taylor 2006; Wilson 2004). Worried about these trends and their social and economic implications, the European Commission identified fertility decline to below 1.5 children per woman to be among the key challenges for policy makers (European Commission 2005). Most countries with fertility below the 1.5 are currently attempting to increase the rate with specific policies (United Nations 2010), with an increase in awareness and declared willingness to intervene from earlier times (Demeny 2003). The OECD explicitly targets the idea to enable people to realize their plans to have children—implying that they have fewer than the desired number (OECD 2011). These concerns are based on past and anticipated trends in period Total Fertility Rates (TFR), although it has been shown that part of the decline in fertility is due to the postponement of fertility (Kohler, Billari and Ortega 2002; Sobotka 2004).

Until very recently, the negative association between fertility and development was one of the most frequent stylized fact and theoretical constructs within the population-development debate (Bongaarts and Watkins 1996; Bryant 2007; Lee 2003). Although socio-economic development was not the leading explanation for fertility differential and trends, the idea that fertility decline was hardly reversible (Bongaarts 1998; Butler 2004; Frejka and Calot 2001; Kohler et al. 2002; Lutz, O'Neill and Scherbov 2003; Lutz, Sanderson and Scherbov 2008) was consistent with a negative development-fertility link. Some recent research, however, has challenged the notion of continuing fertility declines among advanced countries. Using data on fertility and socioeconomic development from 1975 to 2005 for 143 countries, Myrskylä, Kohler and Billari (2009) found that while development continues to promote fertility declines at low and medium levels of development, at advanced development levels further increases in development can reverse fertility decline. The finding on fertility reversing from a negative to a positive association with development among the most advanced countries is consistent with the emerging literature documenting fertility increases for many developed countries before the recession starting in the late-2000s (Caltabiano, Castiglioni and Rosina 2009; Furuoka 2010; Goldstein, Sobotka and Jasilioniene 2009; Luci and Thevenon 2010; Sobotka 2008; Trovato 2010). The most recent set of UN population scenarios incorporates this idea in probabilistic forecasts of fertility, considering a convergence from below-replacement-level to replacement-level fertility for high-development societies as very likely (Alkema et al. 2011). The first indications on the effect of the most recent economic recession (i.e., a decline in socioeconomic development), are consistent with the positive development-fertility link, showing a negative effect on fertility (Sobotka, Skirbekk and Philipov 2011).

In this article, we aim to shed light on the mechanisms underlying the reversal of the development-fertility association by analyzing the links between development and age and cohort patterns of fertility, as well as the role of gender equality. Using data from 1975 to 2008 for over 100 countries, we show that the reversal—from negative to positive—of the link between development and fertility exists both in a period and a cohort perspective and is mainly driven by increasing older reproductive-age fertility. Analyses accounting for changes in the timing of childbearing suggest that while tempo effects contribute to the reversal, increases in the quantum of fertility are an important part of the reversal. We also show that the positive impact of development on fertility in high-development countries is conditional on gender equality: countries ranking high in development as measured by health, income, and education but low in gender equality continue to experience declining fertility. Our findings are robust to a series of checks including regression analyses on a panel of countries.

RECENT FERTILITY INCREASES IN DEVELOPED COUNTRIES: PATTERNS AND MECHANISMS

In 2008, a total of 30 mostly advanced countries had period total fertility (TFR) rates below 1.5, far below the traditional replacement level of slightly more than two, and the average period fertility in 27 European Union countries was only marginally higher at 1.6 (World Bank 2010). In developed East Asian countries fertility is even lower, averaging 1.2 in year 2008 for Singapore, Japan, South Korea and Hong Kong (World Bank 2010). While these are historically very low levels, for many countries they still represent an increase from the lowest levels observed in the 1980s- and 1990s. As documented by Goldstein et al. (2009) and Bongaarts and Sobotka (2011), fertility as measured by the TFR has been increasing in the majority of European countries since 1998. In the period 1998-2008, 18 European countries experienced TFR increases by 0.2 or more from the lowest levels, and these increases were observed throughout Europe (Bongaarts and Sobotka 2011; Goldstein et al. 2009). Taking Europe as a whole, the average TFR has increased from a low of 1.37 in 1999 to 1.56 in 2008 (VID 2010). In the period 1998-2008 TFR has increased also in the English-Speaking countries (for example, U.S., Canada, U.K, Australia) but continued to decline in developed East Asian countries (World Bank 2010).

For most developed countries the new trend of increasing TFR levels can be seen as a positive change, in the sense that increasing fertility may attenuate the pace of population aging and decline, especially in the long-run. The findings of Myrskylä, Kohler and Billari (2009) suggest that these increases in fertility have been driven by continued socioeconomic progress and human development in countries at advanced development states. Consistently with past research on the fertility—development link (e.g., Bongaarts and Watkins, 2006) Myrskylä et al. (2009) use the Human Development Index (HDI) to measure socioeconomic progress and development in a broad sense. The HDI is the primary index used by the United Nations Development Programme (UNDP) to monitor and evaluate broadly-defined human development (UNDP 2011). For each country the HDI combines three dimensions of socioeconomic progress into a single index for each calendar year: (i) health conditions, as measured by the annual life expectancy at birth, (ii) standard of living, as measured by the logarithm of the annual gross domestic product (GDP) per capita at purchasing power parity (PPP) in US dollars, and (iii) human capital, as measured by the average of the annual adult literacy rate (with two-thirds weight) and the combined primary, secondary, and tertiary gross school enrolment ratio (with one-third weight). Figure 1 updates the analysis of Myrskylä et al. (2009) with the newly published data on HDI from the UNDP (2011) and TFR data from the World Bank (2010), and shows the cross-sectional relationship between fertility and development in 1975 and 2008. Figure 1 confirms that also with the most recent data, fertility is negatively associated with development up to HDI levels around 0.80-0.85, but that at higher levels of development the cross-sectional association between HDI and fertility changes from negative to positive. The turn-around point shown in Figure 1 is about .05 lower than in Myrskylä et al. (2009) since here we use the current definition of HDI, introduced in 2011, which is approximately .05 lower at high development levels than the HDI that was used up to 2010 and in Myrskylä et al. (2009). Please see the section Data for more details.

FIGURE 1 ABOUT HERE

Crucial aspects of the reversal of the development-fertility link, however, have not yet been studied in an adequate way. First, the key demographic mechanisms underlying the reversal are not known. What age groups contribute to the reversal? Is the reversal observable from a cohort perspective? These age and cohort patterns are critical for understanding whether the reversal works mainly through changes in the quantum of fertility, or whether the reversal is driven by changes in the timing of fertility. Second, as there are important exceptions to the positive relationship, what factors contribute to triggering the reversal? In particular, is a high level of gender equity—as indicator of societal environments favoring the combination of work and family choices a prerequisite for this reversal? Third, could the reversal in the fertility-development association be mediated by a demographic explanation, in particular by changes in the timing of fertility, which in earlier years has depressed the TFR but in more recent the influence may have become weaker (Bongaarts 2002; Bongaarts and Feeney 1998; Goldstein et al. 2009; Sobotka 2004)?

Throughout the developed world, fertility decline has been accompanied by increasing mean age at first birth (Bongaarts and Sobotka 2011; Frejka, Jones and Sardon 2010; Frejka and Sobotka 2008; Kohler et al. 2002; McDonald and Moyle 2011; Ogawa, Retherford and Matsukura 2006; Sobotka 2004). It is well-known that the postponement of fertility might induce a downward distortion with respect to the actual underlying behavior (Bongaarts and Feeney 1998). If the process of postponement is a transition (Kohler et al. 2002), when the pace of postponement slows down – as is happening in several countries that are at the frontier of socioeconomic development – the distortion may decrease, resulting in a tempo-driven increase in observed period fertility rates (Frejka 2010; Goldstein et al. 2009). Some of the observed reversal in the development-fertility link might be attributable to tempo effects, although the first analyses controlling for changes in the mean age at first did confirm the reversal (Myrskylä et al. 2009). It is, however, possible that socioeconomic development triggers changes in the timing of fertility that can be interpreted as weakening of the tempo effect.

To shed light on whether the development-driven increases in fertility are driven by tempo or quantum, we analyze the fertility reversal by age, with adjustments for the timing of fertility, and by cohort. As fertility postponement means shifting births from younger to older ages, we expect the reversal in period fertility rates to be driven by older age fertility. The analysis of the age and cohort patterns and adjustments for the timing of fertility will help in understanding the quantum versus tempo nature of the fertility reversal. Should the reversal be mainly mediated by the timing of fertility, we would see little if any adjusted association between development and fertility. Similarly, no or negative association between cohort fertility and socioeconomic development would suggest that the reversal is attributable to changes in the timing of fertility, If, however, development is increasing fertility through changes in the quantum, we expect a positive association between development and period fertility net of adjustments for timing of fertility, and a similar positive association between development and cohort fertility.

The second aspect of the reversal that has received so far little attention is the mechanism through which advances in development may reverse fertility declines (Furuoka 2010; Myrskylä et al. 2009). While analyses of the age and cohort patterns will shed light on the demographic mechanism linking development and fertility, a more profound understanding of the mechanism requires a theoretical perspective on the societal-level determinants and the study of the variation in the reversal across different contexts. Given the heterogeneity of institutional, cultural and policy contexts across developed countries, the mechanism through which development increases fertility may not be unique but context-specific. In particular, focusing on the exceptions to the positive association– highly developed countries such as Japan, Canada, or Austria which according to Myrskylä et al. (2009) continue to experience fertility declines – may provide means to further our understanding of the reversal.

Peter McDonald (2000) has argued that sustained low fertility leads to fundamental changes in women's lives. More specifically, he attributes the emergence of very low fertility to clashes between high gender equity in individual-oriented institutions and low gender equity in family-oriented institutions. Gøsta Esping-Andersen (2009) has argued that very low fertility is the by-product of the incomplete transition from an "old" gender-unequal system based on the male breadwinner to a "new" gender-equal system. It is therefore somehow natural to see gender equality as a potentially precondition to reversal of the development-fertility link. Countries rarely reach advanced levels of socioeconomic development without the large-scale participation of women in the labor force.[1] The expansion of female labor force participation typically happens in a context where institutional infrastructure and cultural traditions are not ready to accommodate women who both work and have children, and leads, at minimum temporarily, to declining fertility. Gender equality becomes a key factor for the subsequent adjustment, and the simultaneous mobilization of female labor supply and promotion of gender equality in paid and unpaid work becomes a best practice policy target (OECD 2011).

Despite the relevance of the gender dimensions, attempt to empirically investigate the connection between gender equality and fertility have been limited (Mills 2010). This lack of empirical attention might depend on measurement issue, as several measures of gender (in)equality, built with different aims, are available. For what concerns gender equality as a mediating factor in the development-fertility link, the factors through which gender equality could mediate the impact of development on fertility may be context-specific (Gauthier 2007; Thévenon 2011). Depending on the prevailing culture within a society, the mix of policies may focus on support to working parents with very young children as it is common in the Nordic countries, on financial support targeted on low-income and large families as it is common in Anglo-Saxon countries, or policies may be residual, as it is typical in Southern Europe and East Asian countries (Frejka et al. 2010; Thévenon 2011). The evidence on the effectiveness single policies is mixed. Overall, however, the literature suggests that gender-equality policies may have an impact on fertility, though it is not clear whether these influences are changes in timing or quantum (Gauthier 2007; Luci and Thevenon 2011; McDonald 2006; Neyer and Andersson 2008). It is, however, not clear whether a policy that works in a certain context would have a similar impact in a different context. A prime example is child-care availability, which may have boosted fertility in Sweden (Rindfuss et al. 2010). In a different context, for example in Germany where cultural norms are less favorable to working mothers (Ruckdeschel 2009), the simple provision of affordable childcare has not yet had a visible impact. Thus social norms are potentially important determinants of the mechanisms through which gender equality could influence the development-fertility association, and both the policies that might be implemented to address low fertility, and the efficacy of any policy, are likely to be context specific.

The gap between levels of desired fertility that are reported in surveys and observed period TFRs (D'Addio and D'Ercole 2005; Goldstein, Lutz and Rita Testa 2003; van Peer 2002) suggests that there is demand for policy environments that facilitate childbearing. The unanticipated difficulties in combining family and work are often seen as an important factor limiting women and couples from realizing their fertility intentions. At advanced levels of development, governments may explicitly address low fertility by implementing policies that improve the compatibility between career and children. Countries having high levels of gender equality may be more able than countries lagging behind to develop the institutional structures and new cultural traditions that attenuate the family vs. work conflict.

DATA

The following analyses are based on period and cohort measures of fertility, on socioeconomic development as measured by the Human Development Index and on gender equality measured by the Global Gender Gap index for 176 countries, listed in Appendix Table A.1.

For period fertility, we use both the period Total Fertility Rate (TFR)[2] and age-specific fertility rates at ages 15-29 and 30-49. Our data source for TFR is the World Bank Development Indicators Database (World Bank 2010). For age specific fertility we combine data from the United Nations World Fertility Patterns (United Nations 2009), the Human Fertility Database (2011) and Eurostat (2011) with data obtained from individual researchers and national statistical offices. To measure the timing of fertility, we use data on period mean age at birth, calculated from single-year age single-year period data on fertility rates for 35 countries.[3] For the majority of countries, the data source is the

Human Fertility Database or Eurostat. For Australia, Korea, New Zealand and Japan we have obtained the data from statistical offices or from individual researchers through personal communication (see Appendix for details).

In our cohort analysis we use completed fertility for the 1970 birth cohort, which at the time of writing has not fully completed its childbearing. We use single-year age single-year period data on fertility rates for 35 countries, obtained from the Human Fertility Database, Eurostat, and through personal communication (Appendix for details) as the basis for completing the fertility of this cohort by using the conservative "freeze rates" method in which the last observed age-specific rates, which for most countries are for year 2008, are extrapolated into the future (Cheng and Goldstein 2010).

Similarly to Bongaarts and Watkins (1996), who focus on the fertility-development link, we measure the level of socioeconomic development using the human development index (HDI), computed by the United Nations Development Programme (UNDP). The HDI combines three dimensions of socioeconomic progress, health conditions, standard of living, and human capital, into a single index for each calendar year (UNDP 2011). UNDP occasionally updates the exact definition of the HDI, making comparative and time series analyses challenging. For example, up to 2010 the HDI was calculated as the arithmetic mean of the sub-indexes but in the 2011 revision the method was changed from arithmetic to geometric means, with some additional changes in how the sub-indexes are defined.[4] The only incarnation of HDI that is consistently comparable over time and for which UNDP provides annual time series was introduced alongside the 2011 revision. This version of HDI uses the same functional form (geometric mean) as the 2011 revision of HDI but uses as the sub-indexes for health, education and income the same indicators that were in use up to 2010. The time-consistent index is calculated as the geometric mean of (i) health conditions, as measured by annual life expectancy at birth, (ii) standard of living, as measured by the logarithm of the annual gross domestic product (GDP) per capita at purchasing power parity (PPP) in US dollars, and (iii) human capital, as measured by average of the adult literacy rate and the combined primary, secondary, and tertiary gross school enrolment ratio.[5] UNDP uses this index in its trend analyses. For consistency and comparability, we also use this index, which however deviates slightly from our earlier analyses in Myrskylä et al (2009), where we constructed a longitudinally consistent HDI index from the underlying series of life expectancy, school enrollment and GDP per capita because UNDP had not yet published a longitudinally comparable series.

The time-consistent HDI is calculated using scaling values for each index that are time-invariant. Thus the HDI values are comparable over time within each country. This is an important difference with respect to earlier, pre-1999 definitions of the HDI when the scaling values depended on the current minima and maxima. With fixed scaling values HDI levels can increase beyond the currently observed highest HDI values as development progresses and health conditions, standard of living, and/or human capital levels further improve. The constant scaling values also imply that countries do not necessarily cluster near a maximum value of one as they reach very advanced development stages. The longitudinal consistency of the HDI enables our analyses to identify if and how within-country changes in development levels during 1975–2008 affect trends in fertility.

The time-consistent HDI used in this study, the current geometric specification of HDI and the earlier additive specification of HDI which was used in Myrskylä et al. (2009), are highly similar. For example, the correlations between the time-consistent HDI (hybrid-HDI), the 2011 revision of HDI, and the earlier arithmetic means based HDI are 0.98 or higher for each year 1980, 1985, 1990, 1995, 2000, 2005 and 2008 for which the data is published by UNDP. Thus it is unlikely that by using an alternative definition of the HDI (which is in practice impossible due to the lack of time series data) we would get any different results. The main difference between the indexes is that the geometric means based indexes (both the time-consistent index, and the 2011 revision) are on average 0.05 units lower at high levels of development than the arithmetic means based index that was used up to 2010 and in Myrskylä et al. (2009).[6] Since Myrskylä et al. (2009) observed fertility-development association to reverse from negative to positive in the HDI range 0.85-0.90 using the arithmetic means based HDI, with the time-consistent geometric means based HDI we expect the reversal to take place at .05 units lower HDI level, in the range 0.80-0.85.

We measure gender equality using the World Economic Forum's Global Gender Gap index (Hausmann, Tyson and Zahidi 2010). The GGG index measures gender equality (with high values indicating high equality and low values low equality) in political empowerment, economic participation and opportunity, and health and survival, and educational attainment. The GGG index focuses on measuring gaps rather than levels, thus the index may have high values in an equally deprived context. The GGG also aims to captures gaps in outcome variables rather than gaps in means or input variables. Interestingly, de la Croix and Vander Donckt (2010) use the GGG in their empirical analysis on the relationship between gender empowerment and the start of a fertility transition[7].

RESULTS

In the following four sections, we present our results. First, we analyze the age pattern in the reversal of the development-fertility relationship. Second, we analyze the role of gender equality in this reversal. Third, we analyze the reversal as related to cohort fertility. These sections largely rely on graphical representations of the data. In the fourth section, we employ a longitudinal regression approach in which we assess the robustness of the basic findings on the reversal to country heterogeneity, period trends, and fertility timing.

Age-specific fertility and the reversal of the development-fertility association

Figure 2 extends the cross-sectional picture on the development-fertility link of Figure 1 to age-specific fertility, plotting fertility at ages below and above 30 against the HDI for years 1985 and 2005.[8] Both in 1985 and 2005, fertility at ages below 30 is negatively associated with development up to about HDI level 0.80 (Kendall rank correlations are -0.58, $p<.001$ for year 1985 and -0.56, $p<.001$ for year 2005). At higher HDI levels the association flattens. For the year 1985 the number of observations with HDI above 0.80 is small, but for the year 2005 the rank correlations are 0.00 (n= 13, $p>.10$) in the HDI region 0.80-0.84 and 0.17 (n = 29, $p>.10$) for countries with HDI above 0.85.

Fertility at ages 30 and above is similarly negatively associated with HDI at HDI levels below 0.80. The rank correlations for years 1985 and 2005 are -0.55, $p<.001$ and -0.54, $p<.001$, respectively. However, at HDI level approximately 0.80-0.84, the association becomes positive. For the year 1985 the number of countries with HDI above 0.80 is small, but for the year 2005, the rank correlations between HDI and fertility at ages 30-49 are 0.30 (n= 13, p>.10) in the HDI region 0.80-0.84 and 0.31 (n = 29, p<.05) for countries with HDI above 0.85.

This duality in the cross-sectional relationship between development and fertility by age – consistently negative or flat association between HDI and fertility below age 30, but reversing association between HDI and fertility at ages 30 and above — corresponds to the known idea of fertility postponement, where fertility declines at young but increases at older ages. These cross-sectional analyses confirm that the association reverses from negative to positive at HDI levels approximately around 0.80-0.84, but they specifically show that this reversal is driven by fertility at ages above 30. The "recuperation" of postponed fertility, known to be a key discriminant for the quantum of below-replacement fertility (Billari and Kohler 2004; Frejka et al. 2010; Lesthaeghe 2010; Lesthaeghe and Willems 1999) is therefore also the mechanism behind the reversal of the development-fertility association at high levels of development.

FIGURE 2 ABOUT HERE

Is the cross-sectional pattern also confirmed when we look at country-level trajectories? Figure 3 complements the cross-sectional analysis with a longitudinal perspective by showing country-specific (longitudinal) fertility trajectories. The figure includes TFR-HDI trajectories for all 30 countries for which longitudinal data was available and which by 2008 had reached an HDI of 0.85. The origin of the horizontal axis corresponds to the *reference year*, in which HDI enters the 0.80-0.85 range. This is the HDI range for which cross-sectional plots (and regression estimates in Myrskylä et al. (2009)) suggest the reversal of the HDI-TFR association. Trajectories ending in the top-right quadrant are consistent with the cross-sectional fertility reversal, i.e. with fertility increasing with respect to the reference year. Trajectories ending in the bottom-right quadrant correspond with a further decline of fertility, despite continued advances in development.

FIGURE 3 ABOUT HERE

Figure 3 confirms in a longitudinal perspective what the cross-sectional analyses suggested: in most countries the TFR has increased from the troughs observed in the reference year. While there are exceptions (as for instance Brunei, Singapore, Japan, and Switzerland)[9], the trajectories for the majority of countries confirm in a longitudinal perspective what the cross-sectional analyses suggested: Of the 30 countries, 22 end in the top-right quadrant of the figure, following a "j" shape TFR-HDI pattern. The thick grey line in the figure shows the median trajectory of TFR with respect to HDI, calculated as the median of the country-specific slopes, separately before and after the reference year. The median slope of TFR with respect to HDI at HDI levels up to the reference year is -11.0, suggesting that before the reference year, a 0.05 HDI increase is associated with a 0.55 TFR decrease. The median slope after the reference year is 3.0, suggesting that after the reference year a 0.05 HDI increase is associated with a 0.15 TFR increase.[10]

These results confirm that as development has progressed and these 22 countries attained an advanced HDI level of 0.80 or higher, the earlier downward trend in the total fertility rate was reversed.

As a result, fertility in 2008 was higher than the minimum that was observed while a country's HDI was within the 0.80–0.85 interval. For example, US fertility reversed in 1976 (reference year) at an HDI of 0.81. Since then, fertility has increased from 1.74 to 2.10. In Sweden the reversal occurred in 1978 at an HDI of 0.81; since then TFR has increased from 1.60 to 1.91. In Spain the turning point was in 1995 at an HDI of 0.85, after which TFR has increased from 1.17 to 1.46. Japan, however, exited the HDI region 0.80-0.85 in 1993 with TFR 1.46, and has since seen its fertility decline to 1.34.

Figure 4 shows longitudinal trajectories on the association between HDI and age-specific fertility (the number of countries in these analyses drops because longitudinal age-specific fertility data is not widely available)[11]—the origin of the horizontal axis is located in the usual reference year. Panel A shows trajectories in fertility at ages below 30 and confirms that in almost all countries, younger-age fertility decline has continued even with further advances in development. The median trajectory, calculated as the median of country-specific slopes of age-specific fertility with respect to HDI, suggests that before the reference year a 0.05 HDI increase is associated with a 0.51 decrease in fertility below age 30, while after the reference year a 0.05 HDI increase is associated with a 0.13 decrease in fertility below age 30. Panel B shows fertility trajectories at ages above 30. These are in striking contrast to the ones in panel A, as in all countries fertility above age 30 increases at very high development levels. For some countries, the increase is a continuation of the trend that was present already at lower development levels; for some the increase in fertility with respect to HDI represents a break from the previous downward trend. The median trajectory, calculated as the median of country-specific slopes of age-specific fertility with respect to HDI, suggests that before the reference year, the association between HDI and fertility above age 30 is flat, while after the reference year a 0.05 HDI increase is associated with a 0.24 increase in fertility above age 30. The analysis of these longitudinal age-specific fertility trajectories therefore confirms that a reversal of the development-fertility link can only be attributed to fertility at ages above 30.

FIGURE 4 ABOUT HERE

<u>Gender equality and the reversal of the development-fertility association</u>

While figures 3 and 4 document that, within the general pattern of reversal of the association between development and fertility, there is considerable heterogeneity across countries. Looking at Figure 3 in particular, the fertility of Scandinavian countries and the majority of western European follows an increasing path after the reference year, while several East Asian (Japan, Singapore, South Korea), Middle East (Brunei, Kuwait) and some central European countries (Switzerland, Austria) have continued to experience fertility decline despite further increases in development. As discussed earlier, we consider gender equality as the key potential factor facilitating the fertility increase as development reaches very high level. We do this by analyzing the association between the Global Gender Gap index (GGG) and the pace of fertility increase after HDI has reached the 0.80-0.84 level. The *pace of fertility increase* is measured through the longitudinal slope of the TFR as a linear function of HDI after the reference year (see Figure 3). The pace of fertility increase is positive for the majority of countries, consistently with the reversal of the HDI-TFR relationship but still negative for some countries.

FIGURE 5 ABOUT HERE

Figure 5 plots the pace of fertility increase against the average GGG in years 2006-2010 for all 30 countries for which the data are available. The reporting year for GGG measures gender equality level two years earlier (World Economic Forum 2010). Thus report years 2006-2010 reflect gender equality in 2004-2008, the last five years of observation. Figure 5 includes predicted values from a quadratic regression of the pace of fertility increase on GGG (solid line). The figure shows that gender equality is clearly associated with the pace differences in fertility trajectories at high HDI levels: at GGG levels below 0.65, all countries have a negative pace, representing four important exceptions in Figure 3: South Korea, Japan, Kuwait, and Brunei; at GGG levels below 0.70 almost half of the countries (5 out of 11) have a negative pace; at GGG levels 0.70-.75 the majority of the countries (8 out of 11) have a positive pace, and all 8 countries with GGG above 0.75 have a positive pace. In other words, where gender equality is low, fertility continues to be negatively associated with development; where gender equality is high, we observe the reversal in the development-fertility link. Gender equality seems to convey the environment in which this reversal, and the associated increase in fertility, can be reversed.

Given the importance of this finding, it is useful to assess its robustness. As a first check, some of the association between GGG and the pace of fertility increase might be driven by differences in the initial levels of fertility. For instance, gender unequal countries that continue to experience fertility declines might start from a relatively high *level* of fertility, and this should not be conducive to a reversal implying an increase in fertility. We studied the sensitivity of the GGG-pace of fertility increase association to fertility level. The results, shown in Figure 5 (dashed line), suggest that the positive relationship between the pace of fertility increase and GGG is not driven by low gender-equality countries having higher starting level of fertility: the positive association is robust to controlling for fertility level in the reference year after which the pace of fertility increase is measured.

As a second robustness check, we assessed whether the GGG-pace of fertility increase association might be confounded by the regional clustering of countries. Visual inspection of Figure 5 suggests that countries are regionally clustered in terms of gender equality and fertility recovery. For example, Scandinavian countries rank high along both of these dimensions; Eastern European countries show rapid fertility increase at moderate levels of gender equality (possibly because of the strong fertility postponement experienced in the 1990s); and East Asian countries and wealthy Middle East countries cluster to the region where gender equality is low and fertility trajectories negative. We first assessed the robustness of the positive GGG-pace of fertility increase association to clustering by including controls for regions (Scandinavian, Western European, Eastern European, Mediterranean, Asian, English-speaking, or Middle East). The region-coefficients were individually and jointly not significant ($p>.10$ for each test) while the coefficients for GGG and squared GGG continued to be significant ($p<.10$), with a similar predicted shape between the pace of fertility increase and GGG that was obtained without region controls (results not shown). Second, we removed regions one at a time and regressed the pace of fertility increase on GGG for the remaining data (results not shown). In each of the 7 regressions, GGG continued to have a statistically significant positive association with the pace of fertility increase. The finding that gender equality is positively associated to the pace of fertility increase is robust to unobserved factors at the level of regional clusters of countries.

Cohort fertility and the reversal of the development-fertility association

Our period fertility analyses suggest that the fertility reversal is driven by increasing older-age fertility and that it is conditional on gender equality. The results are consistent with the ideas that the recuperation of fertility at higher ages is essential to reaching higher levels of fertility for advanced societies, and that gender equality is a key factor in the explanation of how these levels can be reached.

FIGURE 6 ABOUT HERE

In our next analyses we show that the cross-country association between development and cohort fertility is not different from those observed for period fertility. For this purpose, Figure 6 plots cohort fertility for the 1970 birth cohort against the average HDI over the years 1995-2005, i.e. when this cohort was aged 25-35. The analysis uses data for all countries for which the data (HDI, gender equality index and fertility rates on an annual basis for single year age groups from 1985 when the 1970 cohort is aged 15 to 2008 when the cohort is aged 38) is available. The 29 countries, listed in a footnote to Figure 6, are mostly the same as those used in Figure 3. The main exceptions are that no data for Middle East countries is available, and that Slovakia, Poland, and Czech Republic are included in Figure 6 but not in Figure 3 as they have not yet exited the HDI window 0.80-0.84. Thus the conclusions of the cohort analysis pertain to European, Asian, and English-speaking countries, but not to Middle East countries. Figure 6 also shows predictions from two quadratic regression models. Model 1 regresses the 1970 cohort fertility on HDI and squared HDI averaged over the years 1995-2005. This model estimates the unadjusted association between cohort fertility and socioeconomic development measured by HDI. As the period analyses suggested that gender equality is an important factor influencing the relationship between period fertility and development, we in Model 2 we estimate the association between cohort fertility and development also with controls for gender equality. Thus Model 2 adds as a control variable to Model 1 the gender equality index GGG averaged over the last five years of observation, 2006-2010. For the GGG index we would use the same years 1995-2005 as we use the HDI, but the data is available only from 2005. If gender equality mediates the positive relationship between development and cohort fertility, we expect the positive association to be weaker or inexistent when controls for gender equality are introduced.

Figure 6 Model 1 shows that cohort fertility has a first decreasing, then increasing association with development, being negative up to HDI level about 0.80-0.85 and positive thereafter. The coefficients for both HDI and HDI squared are statistically significant ($p<.05$). While there is large variation in the levels of cohort fertility at high HDI levels, for example in the region HDI>=0.85 completed fertility ranges from 1.5 for Italy, Germany, Spain and Japan to above 2 for Iceland, New Zealand, Ireland, U.S., Norway and Australia, HDI still explains an large fraction of the overall variance in cohort fertility among advanced countries ($R2 = 0.21$).

As expected, controlling for gender equality in Model 2 attenuates the positive association between completed fertility and HDI at high levels of development: the predictive curve showing the association between cohort fertility and HDI net of GGG still declines up to about HDI level 0.85 and then starts to increase, but not as steeply as in Model 1, and the coefficients for HDI and HDI squared are significant only at the $p=0.10$ level. Further analysis by age (not shown) suggests that the positive association between completed cohort fertility and HDI at high HDI levels is, as was the case for period fertility, attributable to fertility at ages 30 and above.

Results on the 1970 cohort suggest that the HDI-fertility association is bound to reversals also looking from a cohort perspective. As a sensitivity check we studied the association between HDI and completed fertility for the 1960 and 1965 birth cohorts. For both cohorts the cross-country association between HDI and completed fertility similar to what we document in Figure 6 for the 1970 birth cohort: the unadjusted association between completed fertility is U-shaped, and adjusting for gender equality attenuates but does not remove the U-shaped association. Thus development and cohort fertility are negatively associated at low- to moderately high levels of development, while they become positively associated at very high levels of development. Moreover, also looking at the cohort perspective, the reversal of the development-fertility association is conditional on gender equality.

<u>Panel regression analyses of the reversal of the development-fertility association</u>

In the mostly graphical analyses we conducted so far, we could not fully control for country heterogeneity or time trends, which might confound the reversal of the development-fertility association. Although our analysis of the 1970 cohort showed similar findings, the reversal may also be influenced by changes in fertility timing. We now analyze the reversal by using regression models for a panel of countries, with which we can address both of these concerns. More specifically, we estimate regression models that control for unobserved heterogeneity and shared or country-specific time trends, and that adjust the fertility-HDI association for fertility timing by. We use a panel of 35 countries over the years 1975-2008 (all countries and years for which data is available) to estimate the effects of HDI on period fertility using the following four models:[12]

(1) $$TFR_{i,t} = \alpha + \beta_1 HDI_{i,t} + \beta_2 HDI^2_{i,t} + \gamma_i + \theta_t + \varepsilon_{i,t} \,,$$

(2) $$TFR_{i,t} = \alpha + \beta_1 HDI_{i,t} + \beta_2 HDI^2_{i,t} + \gamma_i + \theta_t + \phi_1 \Delta MAB_{i,t} + \phi_2 \Delta\Delta MAB_{i,t} + \varepsilon_{i,t} \,,$$

(3) $$TFR_{i,t} = \alpha + \beta_1 HDI_{i,t} + \beta_2 HDI^2_{i,t} + \gamma_i + \theta_i t + \varepsilon_{i,t} \,,$$

(4) $$TFR_{i,t} = \alpha + \beta_1 HDI_{i,t} + \beta_2 HDI^2_{i,t} + \gamma_i + \theta_i t + \phi_1 \Delta MAB_{i,t} + \phi_2 \Delta\Delta MAB_{i,t} + \varepsilon_{i,t} \,.$$

Here $TFR_{i,t}$ is the dependent variable total fertility rate for country *i* at time *t*; HDI and HDI^2 are the human development index and squared human development index; γ_i and θ_t are country and time fixed effects; ΔMAB and $\Delta\Delta MAB$ are the first and the second difference in mean ages at birth; and $\varepsilon_{i,t}$ is the residual. We estimate the standard errors for each model using panel data bootstrap (10,000 replications) since asymptotic standard errors might be biased downwards in a data of only 35 countries.[13]

The motivation for the four different regression equations is as follows. Model 1 estimates the association between TFR and HDI and controls for shared time trends in TFR through the indicators θ_t

for each year from 1975 to 2008 and for differences in fertility levels across countries through the country fixed effects γ_i. This model provides stronger evidence for a causal relationship than cross-sectional analyses because the model estimates the association between HDI and TFR from within-country variation while controlling for TFR time trends.

Model 2 considers whether the association between HDI and TFR could be mediated by changes in the timing of fertility. This model extends Model 1 by adding controls for first and second order difference in the mean ages at birth (ΔMAB and $\Delta\Delta MAB$). The first difference in the mean age at birth controls for the initial TFR-suppressing effect when fertility starts moving to older ages. The second difference in the mean age at birth controls for the potential increase TFR when the change in mean age at birth slows down and the suppressing effect on TFR weakens. This regression approach is an alternative to using direct tempo-adjustment of fertility and is particularly useful in longitudinal analysis in which tempo-adjustments tend to increase the variance in data, or are not available due to limited information on parity-specific fertility. Endnote 3 discusses further mean age at birth as a covariate in the regression models.

Models 3 and 4 extend Models 1 and 2 by controlling for country specific time trends ($\theta_i t$) instead of estimating a shared time trend with period indicators (θ_t). This may be important as the declining time trends in TFR among less developed countries may influence the coefficient estimated for HDI if the time trends are forced to be shared by statistical design.

TABLE 1 ABOUT HERE

FIGURE 7 ABOUT HERE

Table 1 shows the estimated coefficients for the Models 1-4; Figure 7 illustrates the predicted TFR with respect to HDI for models 1 and 2. The Figure 7 also shows the cross-sectional plot of fertility and HDI for the end point of our analyses, year 2008.[14]

Model 1 confirms what the graphical analyses suggested. Net of unobserved country heterogeneity and shared time trends, period fertility declines with development up to HDI level 0.80-0.84 (the predicted minimum is at HDI=0.82). At higher HDI the association reverses to positive. The coefficients for both HDI and squared HDI are significant at p=.001 level. Figure 7, solid line illustrates the predicted association between TFR and HDI from Model 1.

When controls for the timing of fertility are introduced (Model 2), the positive association between HDI and TFR at high levels of development attenuates but the coefficients for HDI and squared HDI stay significant (p<.01). The coefficients for the first and second differences in mean age at birth are negative and positive, respectively. This suggests – similarly to what Goldstein et al. (2009) have argued regarding the relationship between TFR and mean age at first birth – that when mean age at birth first starts to increase, TFR is suppressed, but when the change in mean age at birth slows down, the suppressing effect attenuates. Figure 7, dashed line illustrates the predicted association between TFR and HDI from Model 2. Comparing Model 1 (solid line) and Model 2 (dashed line) confirms that controls for the timing of fertility do not remove the positive association between TFR and HDI at HDI levels above approximately 0.85 (the predicted minimum is at HDI=0.83).

Models 3 and 4 extend the Models 1 and 2 by allowing the time trends in fertility to be country specific. The country-specific time-trends and country fixed effects themselves explain 85% of the variation in TFR, leaving relatively little statistical power to estimate the coefficients for HDI. For Model 3, however, the coefficients for both HDI and HDI squared are statistically significant ($p<.05$) and the estimated association between TFR and HDI continues to be U-shaped with minimum TFR obtained at HDI level 0.80. For Model 4 the coefficients for both HDI and HDI squared lose statistical significance, but the predicted association between TFR and HDI stays qualitatively similar to what it was in Model 2, being U-shaped with minimum TFR obtained at HDI level 0.81. The lack of statistical significance in Model 4 may be a power issue, as the country-specific time trends and fixed effects remove the majority of variation in TFR. Nevertheless the results obtained with controls for country-specific time-trends (Models 3 and 4) are qualitatively consistent with those obtained with shared time trends (Models 1 and 2), all suggesting that the association between TFR and HDI reverses from negative to positive at HDI level approximately 0.80-0.85.

DISCUSSION

The reversal – from negative to positive – of the link between socioeconomic development and fertility at high levels of development, and the related upsurge in fertility in several advanced societies that had fallen to unprecedented low fertility levels have been recent important findings (Caltabiano et al. 2009; Furuoka 2010; Goldstein et al. 2009; Luci and Thevenon 2010; Myrskylä et al. 2009; Trovato 2010). Several key aspects of this reversal, however, have not yet been explored. In particular, the demographic mechanism: in this paper we showed that the reversal of the fertility-development association exists both in period and cohort perspectives and is mainly driven by the increasing fertility at older reproductive ages. For what concerns the determinants, we showed that the reversal is conditional on gender equality: countries ranking high in development, as measured by health, income and education, but low in gender equality continue to see declining fertility. Gender equality is therefore crucial for countries wishing to reap the fertility benefits of development.

Analyses by age and cohort answer the critical question regarding the reversal in period fertility trends: is the reversal driven by increases of the quantum of fertility, or is the reversal only due by changes in the timing of fertility? Our different analyses consistently showed that fertility above age 30 is the key to the reversal of the development-fertility link. For what concerns fertility below age 30, cross-sectional and longitudinal analyses showed a continuous decline, with no reversal. Regression analyses, which allow to control for country heterogeneity and time trends showed that all ages combined the association between HDI and TFR is positive at high HDI levels. These results were robust to controls for the changes in mean age at childbearing, i.e. to the timing of fertility. In general, findings on the reversal of the fertility–development relationship are robust with respect to the limitations of the TFR as an indicator of fertility levels in developed countries with an ongoing postponement of childbearing (Sobotka and Lutz 2009). The analysis of the link between development and the fertility of the 1970 birth cohort also showed that for countries in which such cohort experienced HDI levels above 0.85 in their prime childbearing years, fertility was higher with respect to countries in which the cohort experienced fertility rates in the region 0.80-0.85. The cohort patterns, and the robustness of the regression results to adjustments for mean age at birth, suggest that the positive association of development with fertility exists net of changes in the timing of fertility. While changing in mean age at birth at advanced levels of development contributes to the reversal, and may even be part of the mediating mechanism, our results suggest that the reversal exists net of the recuperation in TFR that may result from changes in the timing of fertility.

Exploiting the heterogeneous trajectories of countries that cross the “critical” region of development (HDI approximately 0.80-0.85), we could investigate the role of gender equality. We showed that the Global Gender Gap index is a powerful predictor for whether a country is on a declining or increasing fertility trajectory after this “critical” region is reached. An adequate level of gender equality seems therefore a precondition for the reversal that implies increasing fertility at advanced levels of developments. The heterogeneity of advanced countries that rank high in gender equality and experience fertility increases suggests that the way countries address the problem of combining work and family is context specific. Despite this, our results help understand what kinds of institutional settings facilitate the fertility reversal. Earlier research has speculated that failure to answer to the challenges of development with institutions that facilitate work–family balance and gender equality might explain the exceptional pattern for rich eastern Asian countries that continue to be characterized by a negative HDI–fertility relationship. Our analyses confirm this by showing that the reversal is conditioned by gender equality.

Our analyses have three key limitations. First, it has been speculated that the reversal in the fertility-development association could be driven by growing immigrant populations, with higher fertility than the native population (Hugh 2009; Parker 2009; Reebs 2009; Yong 2009). While migrant fertility may explain part of the recent fertility increase in some highly developed societies, it is unlikely that migrants would be the main factor driving the fertility increases. Studying the impact of migrants’ fertility on TFRs in several European countries, Sobotka (2008) concludes that, while immigrants contribute substantially to the total number of births and their share has increased in the last decade, the net effect of the higher fertility of migrants on the total fertility rate is small. The analyses further indicate that the recent upswings in period TFR are mainly due to the rise in the TFR of the native populations (Sobotka 2008). Goldstein et al. (2009) reach a similar conclusion by analyzing the contribution of immigrant women on TFR in seven European countries. For example in Spain, fertility of native women increased from 1.12 in 1998 to 1.30 in 2006, while the overall TFR increased from 1.15 to 1.35. In Italy, the 2007 TFR of the native-born population is 1.28, substantially above the lowest TFR rate of 1.19 observed for the total population—native and immigrant population combined— in 1995, and only 0.07 below the overall Italian TFR for 2007. The relatively small effect of immigration on fertility increases in European countries is in part due to migrants coming from lower fertility countries than the receiving country. But even in the U.S., where migrants come from higher fertility regions, the TFR of non-Hispanic White population has increased from 1.77 in 1989 (the first year for which the data are available) to 1.86 in 2006 (5.3% increase), while the overall increase in TFR in the same period has been from 2.01 to 2.10 (4.3% increase) (Martin et al. 2009). It thus seems that recent increases in the total fertility rate of the native born population are often of similar magnitude than that of the overall total fertility rate. Our interpretation that increases in HDI result in increases in the total fertility rate as a result of behavioral change—rather than due to compositional changes via immigration—is therefore not called into doubt by recent patterns of immigration into highly developed countries.

Second, due to data limitations our measures of gender equality were cross-sectional. Gender equality may have different effects on fertility as the economic role of women progresses in societies (McDonald 2000). First, when equality on the labor market increases, fertility may decrease due to rising opportunity costs of having children. Later, as advanced societies acknowledge the issues working mothers and couples with children face, increasing gender equality may be pivotal in facilitating the development of institutions and social norms that help combining work and family (Mills 2010). Further research might gain insights into these processes from longitudinal analyses of the relationship between gender equality and fertility trends.

Third, our analyses of cohort fertility were based on a single cohort, the 1970 birth cohort. Given the need to analyze cohorts that have experienced the passage through very high development, i.e. cohorts born in the 1970s or 1980s, we need to wait for another decade. Alternatively, the analyses would need to be based on forecasted fertility, which is clearly beyond the scope of the current paper. Using historical data, however, we documented that the U-shaped association between completed cohort fertility and development is observed also for the 1960 and 1965 birth cohorts.

These results extend and provide additional support for the finding that increases in development are an important driving factor of fertility reversals in developed countries. In particular, the results suggest that development contributes to fertility beyond tempo effects, and that gender equality is crucial for countries wishing to reap the fertility benefits of development. The development driven fertility reversal may have important long-run implications as increasing fertility at the highest levels of socioeconomic development may help decrease the rates of population aging and ameliorate the social challenges that have been associated with low fertility.

TABLES AND FIGURES

Table 1. Panel regression of total fertility rate (TFR) on human development index (HDI).

	Model 1	Model 2	Model 3	Model 4
Human development index	-90.73***	-63.61***	-51.12*	-29.91
Squared human development index	55.12***	38.15***	31.89*	18.55
Mean age at birth, first difference		-0.84**		0.61*
Mean age at birth, first difference		0.43**		0.29*
Country fixed effects	Y	Y	Y	Y
Time fixed effects (shared)	Y	Y		
Country specific time trends			Y	Y
HDI level at which the model implies a reversal in the HDI-TFR association (-HDI/(2HDI^2)	0.823	0.834	0.802	0.806
N	962	962	962	962
Number of countries	35	35	35	35
R2 (within)	0.41	0.48	0.71	0.72

*p<.05 **p<.01 ***p<.001

Model 1: Panel regression of TFR on HDI and HDI squared, with country and time fixed effects (dummies for each calendar year).

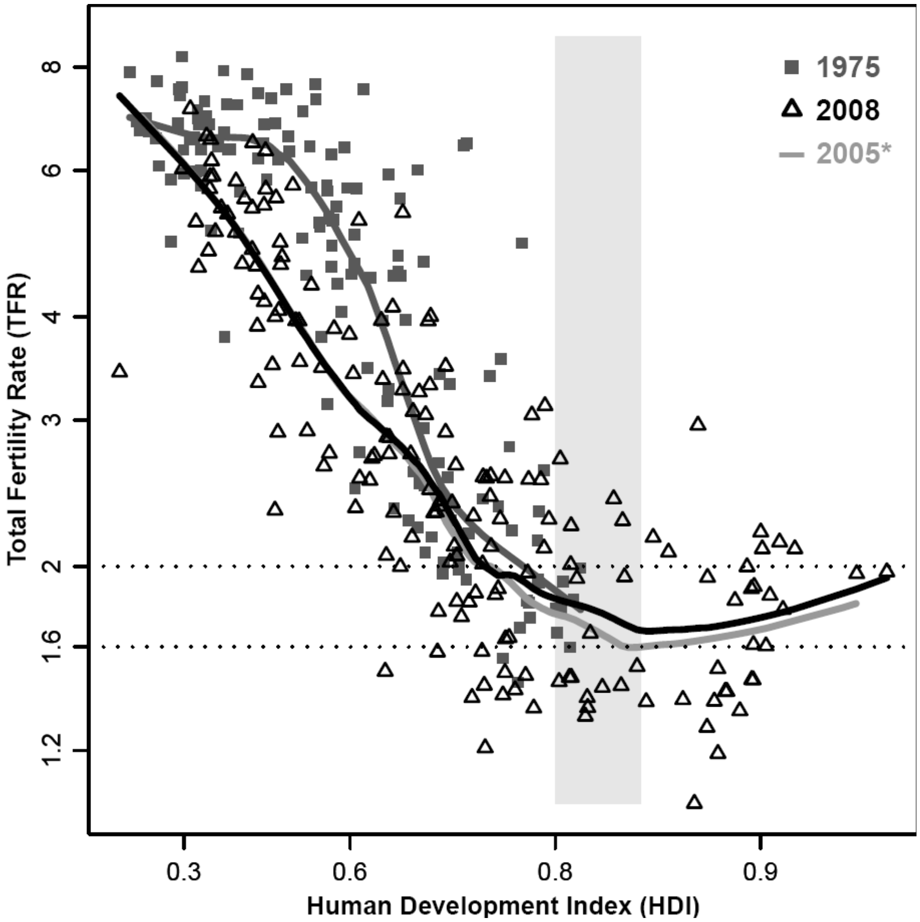
Model 2: Adds first and second differences in mean age at birth to Model 1.

Model 3: Like Model 1, but replaces the shared time fixed effects by country-specific time trends.

Model 4: Like Model 2, but replaces the shared time fixed effects by country-specific time trends.

Notes:
(1) We have included all countries for which annual time-series are available for TFR, HDI, and mean age at birth and which have reached the HDI level 0.75. These countries are: Australia, Austria, Belgium, Bulgaria, Canada, Czech Republic, Denmark, Estonia, Finland, France, Germany, Greece, Hungary, Iceland, Ireland, Italy, Japan, Lithuania, Luxembourg, Netherlands, New Zealand, Norway, Poland, Portugal, Romania, Russian Federation, Singapore, Slovakia, Slovenia, South Korea, Spain, Sweden, Switzerland, U.K., U.S.

Figure 1. Cross-country relationship between Total Fertility Rate (TFR) and Human Development Index (HDI), years 1975, 2005 and 2008: Data points and a lowess curve.



Notes:

(1) For clarity we show only the lowess curve, not data points, for the year 2005.

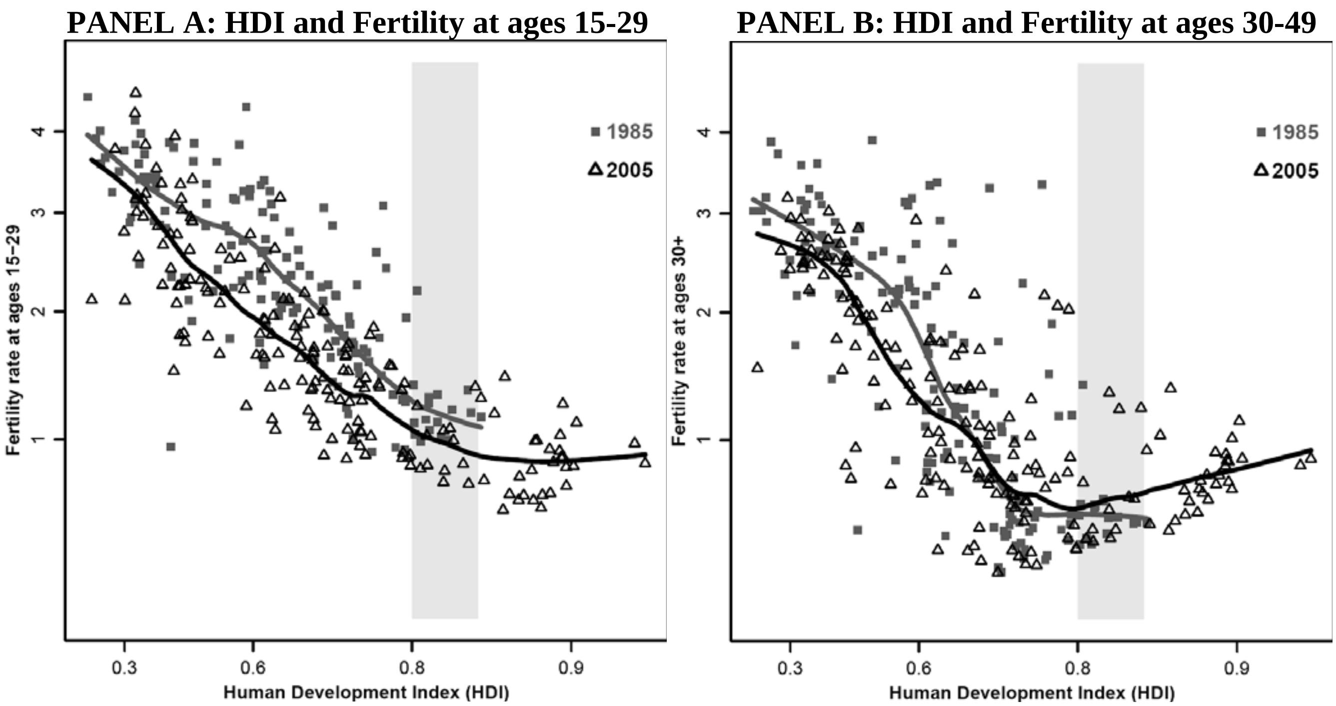
(2) Countries with year 2008 HDI in the range 0.80-0.84: Argentina, Chile, Croatia, Czech Republic, Estonia, Hungary, Latvia, Libya, Lithuania, Malta, Poland, Qatar, Slovakia, Uruguay.

(3) Countries with year 2008 HDI >= 0.85: Australia, Austria, Belgium, Brunei, Canada, Denmark, Finland, France, Germany, Greece, Hong Kong, Iceland, Ireland, Israel, Italy, Japan, South Korea, Kuwait, Luxembourg, Netherlands, New Zealand, Norway, Portugal, Singapore, Slovenia, Spain, Sweden, Switzerland, U.K., U.S.

(3) We confirmed the significance of the positive TFR-HDI correlation at high HDI levels by calculating the Kendall tau rank correlation between TFR and HDI for the year 2008. For the HDI ranges <0.80, 0.80-0.84, and >=0.85 the correlations were -0.63 (n = 126, p<.001), 0.01 (n= 18, p>.10) and 0.29 (n = 30, p<.05), respectively. The correlations were similar for other years.

(4) The axes are scaled to allow focusing on developed low- to moderate fertility countries while preserving the less-developed countries in the figure. We use HDI*=-log(1-HDI) and TFR*=log(.49*TFR)/31, where 0.49 and 31 approximate the probability of a newborn being female and the mean age at birth, respectively. While the positive HDI-TFR association at high HDI levels is observed independently of the transformations (Appendix Figure A.1), there are strong conceptual reasons for these. An important reason for analyzing TFR is to assess the effect of fertility on long-term population dynamics. For this purpose, demographers usually refer to stable population theory, which relates fixed fertility and mortality rates to long-term population dynamics (Preston, Heuveline and Guillot 2001). Differences in the long-term population growth rate are proportional to the log of TFR, so that small TFR differences have larger influence in low than in high fertility settings. This is reflected in the log-scaling of TFR in Figure 1. The HDI-scaling is appropriate to emphasize differences in HDI levels among advanced countries that cluster within a relatively narrow HDI range.

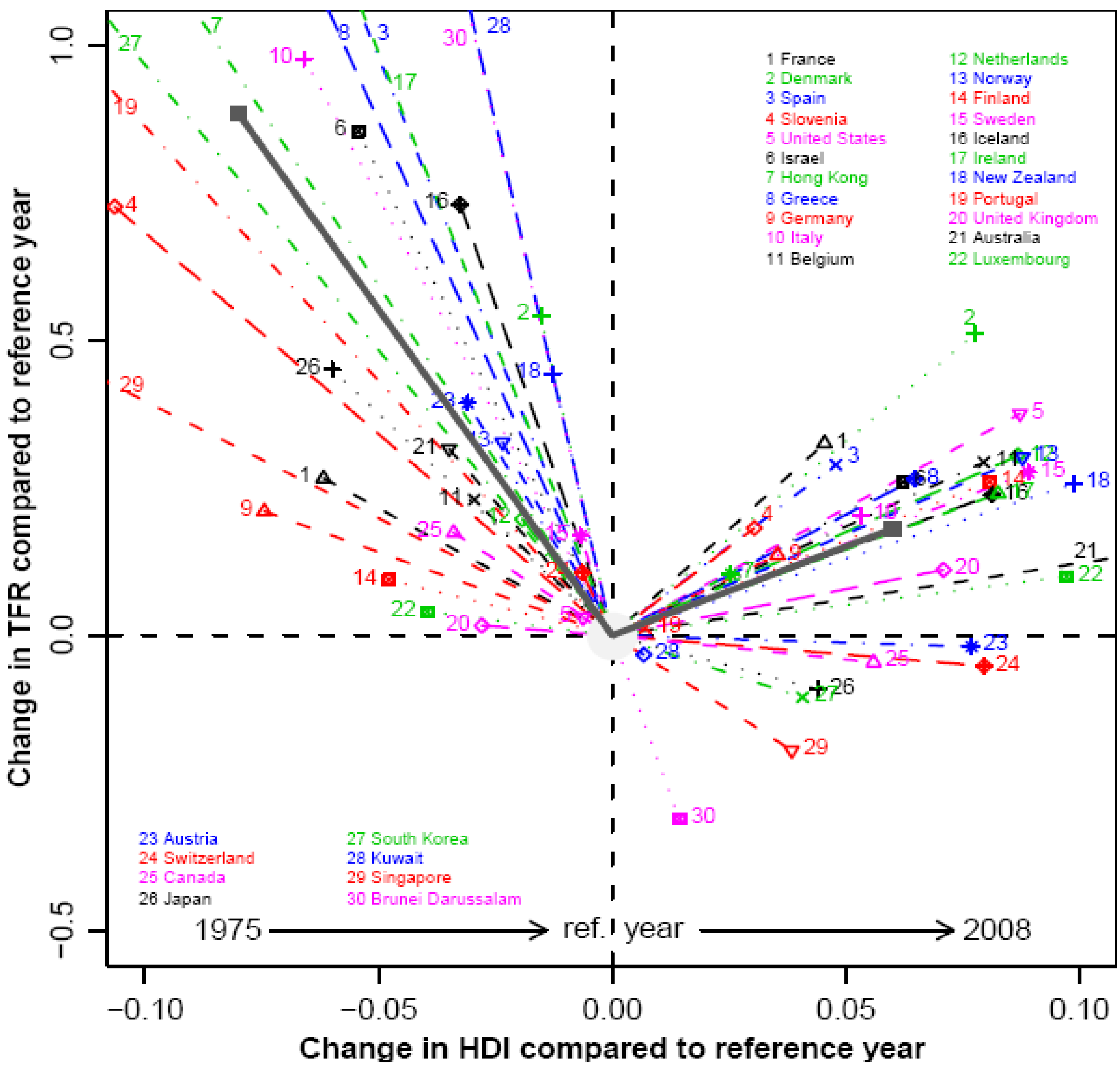
Figure 2. Cross-country relationship between fertility by age and Human Development Index (HDI), years 1985 and 2005. Panel A: Ages 15-29; Panel B: Ages 30 and above.



Notes:
(1) As in Figure 1 the axes are scaled using log-transformations as follows: x-axis scaling: TFR*=log(1+0.49*TFR)/3l; y-axis scaling: HDI*=-log(1-hdi).

(2) We confirmed the flattening of the fertility-HDI relationship for ages below 30 and the reversal from negative to positive for ages 30 and above at high HDI levels by calculating the Kendall tau rank correlation between age-specific fertility and HDI for the year 2005. For fertility at ages 15-29 the correlations were -0.56 (n = 130, p<.001), 0.00 (n= 13, p>.10) and 0.17 (n = 29, p>.10) for the HDI ranges <0.80, 0.80-0.84, and >=0.85, respectively. For fertility at ages 30-49 the correlations were -0.54 (n = 127, p<.001), 0.30 (n= 13, p>.10) and 0.31 (n = 29, p<.05) for the HDI ranges <0.80, 0.80-0.84, and >=0.85, respectively.

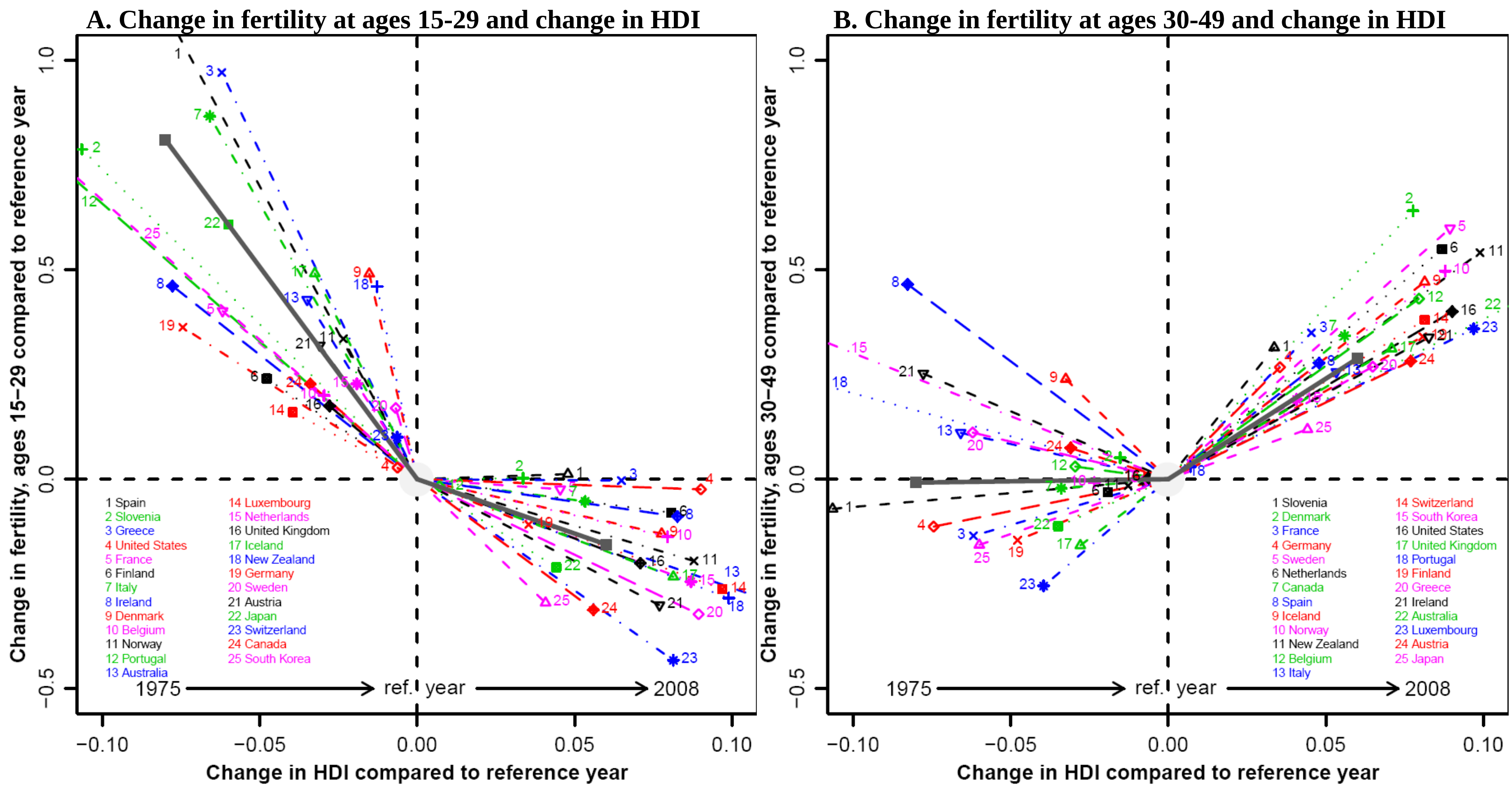
Figure 3. Longitudinal relationship between total fertility rate (TFR) and Human Development Index (HDI).



Notes

(1) The figure shows for each country the starting point (which for most countries corresponds to year 1975; but for a handful of countries the data starts later), the critical point in which the country's HDI was in the window 0.80-0.84 and fertility was at its lowest within this window, and the end point. The starting and end points are calculated with respect to the critical point. The critical point is scaled to (0,0) on the HDI-TFR plane. The starting corresponds to the first year of observation, and shows the TFR and HDI difference with respect to the reference year. Correspondingly, the end point is calculated from the last year of observation and shows the TFR and HDI difference with respect to the reference year. The figure includes all countries that attained an HDI >= 0.85 in 2008 and for which longitudinal data on TFR was available. For all countries, the HDI in 2008 is higher than the HDI in the reference year; for 22 of the 30 countries that attained a HDI >= 0.85 by 2008, the TFR in 2008 is higher than the TFR in the reference year. The thick grey line is the median of the observed trajectories.

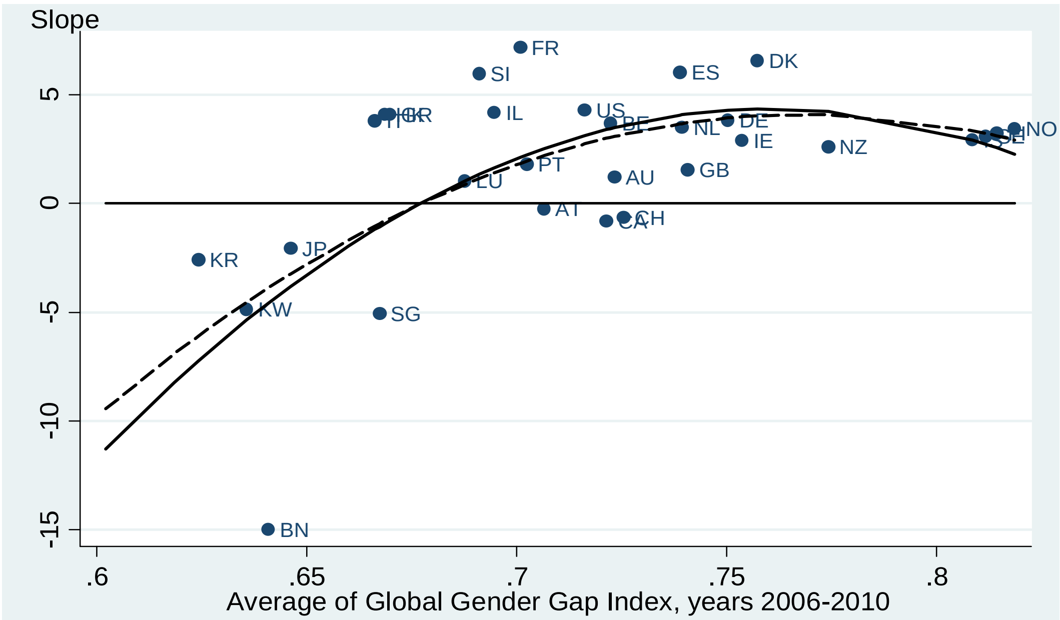
Figure 4. Longitudinal relationship between fertility by age and Human Development Index (HDI).



Notes

(1) The figure shows for each country the starting point (which for most countries corresponds to year 1975; but for a handful of countries the data starts later), the critical point in which the country's HDI was in the window 0.85-0.90 and TFR was at its lowest within this window, and the end point. The thick grey line is the median of the observed trajectories.

Figure 5. Pace of TFR increase with respect to HDI (slope) and gender equality. Data sources: Global Gender Gap Index: World Economic Forum. Pace of TFR with respect to HDI: Own calculations based on data from UNDP (HDI) and World Bank Development Indicators and Human Fertility Database (TFR).



Solid line: Model 1, Regression of Pace of TFR increase with respect to HDI on GGG and squared GGG. Coefficients for both GGG and GGG squared are statistically significant (p<.05); R2 = 0.35.

Dashed line: Model 2, Regression of Pace of TFR increase with respect to HDI on GGG and squared GGG with additional controls for TFR in the reference year. Coefficients for both GGG and GGG squared are statistically significant (p<.05); R2 = 0.53.

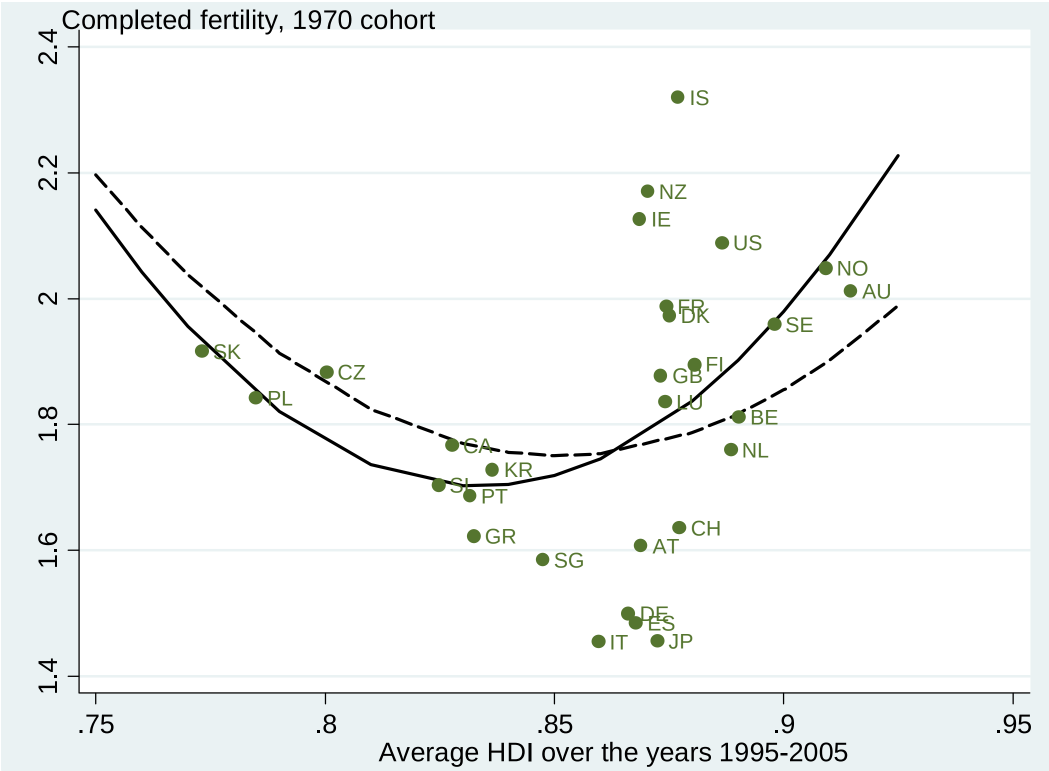
Notes:

(1) Vertical axis: Pace of TFR with respect to a unit change in HDI at advanced HDI levels.

(2) Horizontal axis: Global Gender Gap (GGG) index averaged over 2006-2010.

(3) Pace of TFR with respect to HDI is calculated as the change in TFR divided by change in HDI after the year when HDI was in the range 0.80-0.84 and TFR was at its lowest within this HDI window (see Figure 3 for additional details).

Figure 6. Completed fertility for the 1970 birth cohort HDI, and Gender Equality. Data sources: HDI UNDP. Completed cohort fertility own calculations based on data sources listed in Table A.1. Global Gender Gap (GGG) index World Economic Forum.



Solid line: Model 1, Regression of cohort fertility on HDI and squared HDI. Coefficients for both HDI and HDI squared are statistically significant ($p<.05$); $R2 = 0.21$.

Dashed line: Model 2, Regression of cohort fertility on HDI, squared HDI and gender equality index GGG. Coefficients for both GGG and GGG squared are significant ($p<.10$); $R2 = 0.40$.

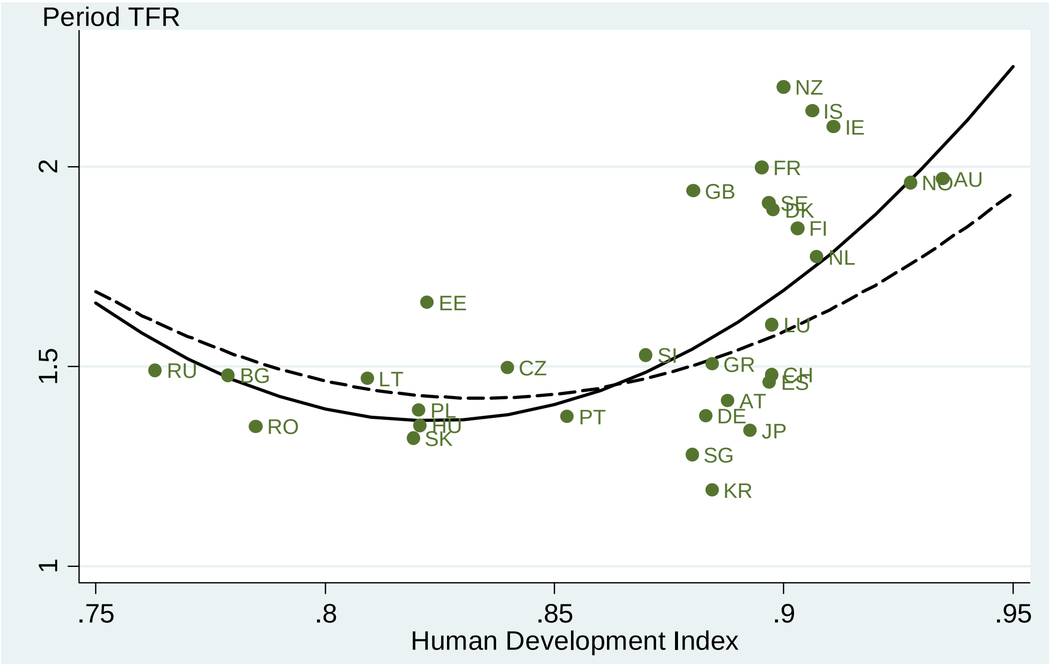
Notes:

(1) The figure shows the association between completed fertility for the 1970 birth cohort and average HDI for the years 1995-2005 when the 1970 cohorts were in their prime childbearing years, aged 25-35.

(2) Cohort fertility is estimated using the simple and conservative “freeze rates” method in which the last observed age-specific rates are extrapolated into the future (Cheng and Goldstein 2010).

(3) Countries included are all countries for which the relevant data is available (the gender equality index, HDI, and fertility rates on an annual basis for single year age groups from 1985 when the 1970 cohort is aged 15 to 2008). The countries are Slovakia, Poland, Czech Republic, Slovenia, South Korea, Greece, Portugal, Canada, Singapore, Ireland, Italy, Luxembourg, Spain, New Zealand, Iceland, Denmark, Germany, Austria, Finland, Switzerland, Japan, France, Sweden, United Kingdom, United States, Belgium, Netherlands, Norway, Australia, Norway, Australia.

Figure 7. Predicted TFR trajectories by HDI, and scatter plot of TFR and HDI in 2008 for 35 countries. Data sources: HDI UNDP. TFR World Bank Development Indicators. Mean age at birth own calculations based on data sources listed in the Appendix.



Solid line: Model 1, Panel regression of TFR on HDI and squared HDI with indicator controls for country and time fixed effects. Coefficients for both HDI and HDI squared are statistically significant (p<.001); R2 (within) = 0.41.

Dashed line: Model 2, Panel regression of TFR on HDI and squared HDI with indicator controls for country and time fixed effects and additional controls for first and second differences in mean age at birth. Coefficients for both HDI and HDI squared are statistically significant (p<.001) and for first and second order changes significant at the threshold p=.01; R2 (within) = 0.48.

Notes

(1) We have included all countries for which annual time-series are available for TFR, HDI, and mean age at birth and which have reached the HDI level 0.75. These countries are: Australia, Austria, Belgium, Bulgaria, Canada, Czech Republic, Denmark, Estonia, Finland, France, Germany, Greece, Hungary, Iceland, Ireland, Italy, Japan, Lithuania, Luxembourg, Netherlands, New Zealand, Norway, Poland, Portugal, Romania, Russian Federation, Singapore, Slovakia, Slovenia, South Korea, Spain, Sweden, Switzerland, U.K., U.S.

APPENDIX

The data sources used in this study are as follows:

Total fertility rate (TFR)
World Bank Development Indicators Online Database (World Bank 2010),
http://data.worldbank.org/data-catalog/world-development-indicators

HDI (hybrid Human Development Index)
United Nations Development Programme (2011), http://hdr.undp.org/en/statistics/hdi/

Completed Fertility Rate (CTFR) for the 1970 birth cohort and Mean Age at Birth (MAB)
Own calculations based on data from the following sources:

Eurostat Online Database (2011), http://epp.eurostat.ec.europa.eu, for Belgium, Bulgaria, Denmark, Estonia, Finland, France, Greece, Hungary, Iceland, Ireland, Italy, Lithuania, Luxembourg, Netherlands, Poland, Portugal, Romania, Slovenia, Spain, United Kingdom

Human Fertility Database (2011), http://www.humanfertility.org, for Austria, Canada, Czech Republic, Germany, Norway, Russian Federation, Slovakia, Sweden, Switzerland, United States

South Korea: Kwang-Hee Jun, Professor of Demography and Sociology, Chungnam National University

Singapore: Statistics Singapore (2010), http://www.singstat.gov.sg

Japan: Ryuichi Kaneko, National Institute of Population and Social Security Research in Japan, and Rikiya Matsukura, Nihon University Population Research for Institute in Japan for

Taiwan: Statistical Yearbook of the Republic of China (2011), http://eng.stat.gov.tw

Australia: Statistics Australia (2010), (http://www.abs.gov.au

New Zealand: Statistics New Zealand (2010), http://www.stats.govt.nz

Age-specific fertility (period fertility at ages 15-29 and at ages 30 and above)
Population Division of the Department of Economic and Social Affairs of the United Nations Secretariat (2009), and the above mentioned sources used for calculating cohort fertility.

Global Gender Gap Index (GGG)
World Economic Forum (2010), http://www.weforum.org

Appendix Table A.1. List of countries used in the analysis, and their TFR and HDI for the years 1975 and 2008, completed fertility for the 1970 birth cohort, and average of the Global Gender Gap index for the years 2006-2010.

	Country	ISO abbrev.	TFR 1975	TFR 2008	HDI 1975	HDI 2008	Completed fertility, 1970 birth cohort	Average Global Gender Gap Index, 2006-2010
1	Australia	AU	2.15	1.97	0.79	0.93	2.03	0.72
2	Norway	NO	1.99	1.96	0.82	0.93	2.06	0.82
3	Iceland	IS	2.61	2.14	0.79	0.91	2.33	0.81
4	Ireland	IE	3.40	2.10	0.75	0.91	2.15	0.75
5	Netherlands	NL	1.66	1.78	0.80	0.91	1.76	0.74
6	Canada	CA	1.82	1.60	0.81	0.90	1.78	0.72
7	Denmark	DK	1.92	1.89	0.80	0.90	1.98	0.76
8	Finland	FI	1.69	1.85	0.77	0.90	1.90	0.81
9	France	FR	1.93	2.00	0.79	0.90	2.00	0.70
10	Luxembourg	LU	1.55	1.61	0.76	0.90	1.85	0.69
11	New Zealand	NZ	2.33	2.20	0.79	0.90	2.18	0.77
12	Spain	ES	2.79	1.46	0.77	0.90	1.50	0.74
13	Sweden	SE	1.78	1.91	0.80	0.90	1.97	0.81
14	Switzerland	CH	1.60	1.48	0.81	0.90	1.65	0.73
15	United States	US	1.77	2.10	0.80	0.90	2.10	0.72
16	Austria	AT	1.82	1.41	0.78	0.89	1.61	0.71
17	Belgium	BE	1.74	1.82	0.78	0.89	1.83	0.72
18	Italy	IT	2.21	1.41	0.77	0.89	1.47	0.67
19	Japan	JP	1.91	1.34	0.79	0.89	1.47	0.65
20	Germany	DE	1.45	1.38	0.77	0.88	1.51	0.75
21	Greece	GR	2.37	1.51	0.76	0.88	1.63	0.67
22	Israel	IL	3.55	2.96	0.76	0.88		0.69
23	Singapore	SG	2.08	1.28	0.69	0.88	1.59	0.67
24	South Korea	KR	3.47	1.19	0.62	0.88	1.73	0.62
25	United Kingdom	GB	1.81	1.94	0.78	0.88	1.89	0.74
26	Hong Kong	HK	2.67	1.04	0.70	0.87		0.67
27	Slovenia	SI	2.20	1.53	0.73	0.87	1.71	0.69
28	Brunei Darussalam	BN	4.90	2.08	0.78	0.86		0.64
29	Kuwait	KW	6.44	2.17	0.73	0.86		0.64
30	Cyprus	CY	2.35	1.52	0.66	0.85		0.66
31	Portugal	PT	2.52	1.37	0.68	0.85	1.69	0.70
32	Antig. and Barbuda	AG	2.43			0.84		
33	Bahrain	BH	5.56	2.27	0.66	0.84		0.60
34	Czech Republic	CZ	2.43	1.50	0.74	0.84	1.89	0.68
35	Qatar	QA	6.47	2.41	0.73	0.84		
36	United Arab Emir.	AE	6.01	1.94	0.68	0.84		0.62
37	Malta	MT	2.27	1.43	0.67	0.83		
38	Estonia	EE	2.08	1.66	0.72	0.82	1.87	
39	Hungary	HU	2.35	1.35	0.71	0.82	1.88	
40	Poland	PL	2.27	1.39	0.72	0.82	1.84	

Appendix Table A.1, continued.

	Country	ISO abbrev.	TFR 1975	TFR 2008	HDI 1975	HDI 2008	Completed fertility, 1970 birth cohort	Average Global Gender Gap Index, 2006-2010
41	Slovakia	SK	2.56	1.32	0.71	0.82	1.92	
42	Argentina	AR	3.32	2.24	0.71	0.81		
43	Chile	CL	3.16	1.93	0.65	0.81		
44	Croatia	HR	2.00	1.47	0.72	0.81		
45	Lithuania	LT	2.19	1.47	0.73	0.81	1.76	
46	Uruguay	UY	2.93	2.01	0.69	0.81		
47	Latvia	LV	1.96	1.45	0.71	0.80		
48	Libya	LY	7.51	2.70	0.62	0.80		
49	Seychelles	SC		2.28	0.69	0.80		
50	Mexico	MX	5.93	2.10	0.65	0.79		
51	Saudi Arabia	SA	7.31	3.12	0.55	0.79		
52	Venezuela	VE	4.66	2.54	0.69	0.79		
53	Bulgaria	BG	2.23	1.48	0.68	0.78	1.66	
54	Costa Rica	CR	3.97	1.96	0.67	0.78		
55	Oman	OM	7.20	3.05	0.42	0.78		
56	Panama	PA	4.48	2.55	0.66	0.78		
57	Romania	RO	2.60	1.35	0.68	0.78	1.62	
58	Saint Kitts and Nev.	KN				0.78		
59	Belarus	BY	2.17	1.42	0.70	0.77		
60	Montenegro	ME	2.38	1.64		0.77		
61	Brazil	BR	4.50	1.88	0.60	0.76		
62	Dominica	DM				0.76		
63	Grenada	GD	4.44	2.28		0.76		
64	Lebanon	LB	4.54	1.85	0.66	0.76		
65	Malaysia	MY	4.59	2.56	0.57	0.76		
66	Russian Federation	RU	1.98	1.49	0.72	0.76	1.60	
67	Serbia	RS		1.4		0.76		
68	Trinidad and Tob.	TT	3.41	1.64	0.70	0.76		
69	Bosnia and Herz.	BA	2.41	1.21		0.75		
70	Colombia	CO	4.63	2.43	0.61	0.75		
71	Ecuador	EC	5.72	2.56	0.60	0.75		
72	Macedonia	MK	2.65	1.44	0.68	0.75		
73	Peru	PE	5.70	2.57	0.61	0.75		
74	Turkey	TR	5.13	2.11	0.56	0.75		
75	Albania	AL	4.45	1.86	0.63	0.74		
76	Azerbaijan	AZ	3.95	2.30	0.64	0.74		
77	Kazakhstan	KZ	3.27	2.56	0.65	0.74		
78	Mauritius	MU	3.14	1.58	0.57	0.74		
79	Saint Lucia	LC		2.01		0.74		
80	Ukraine	UA	2.02	1.39	0.71	0.74		
81	Armenia	AM	2.75	1.74	0.61	0.73		
82	Iran	IR	6.41	1.81	0.54	0.73		
83	Dominican Republic	DO	5.19	2.65	0.56	0.72		
84	Jamaica	JM	4.48	2.39	0.65	0.72		
85	Saint Vincent and the Gren.	VC	4.97	2.12	0.53	0.72		

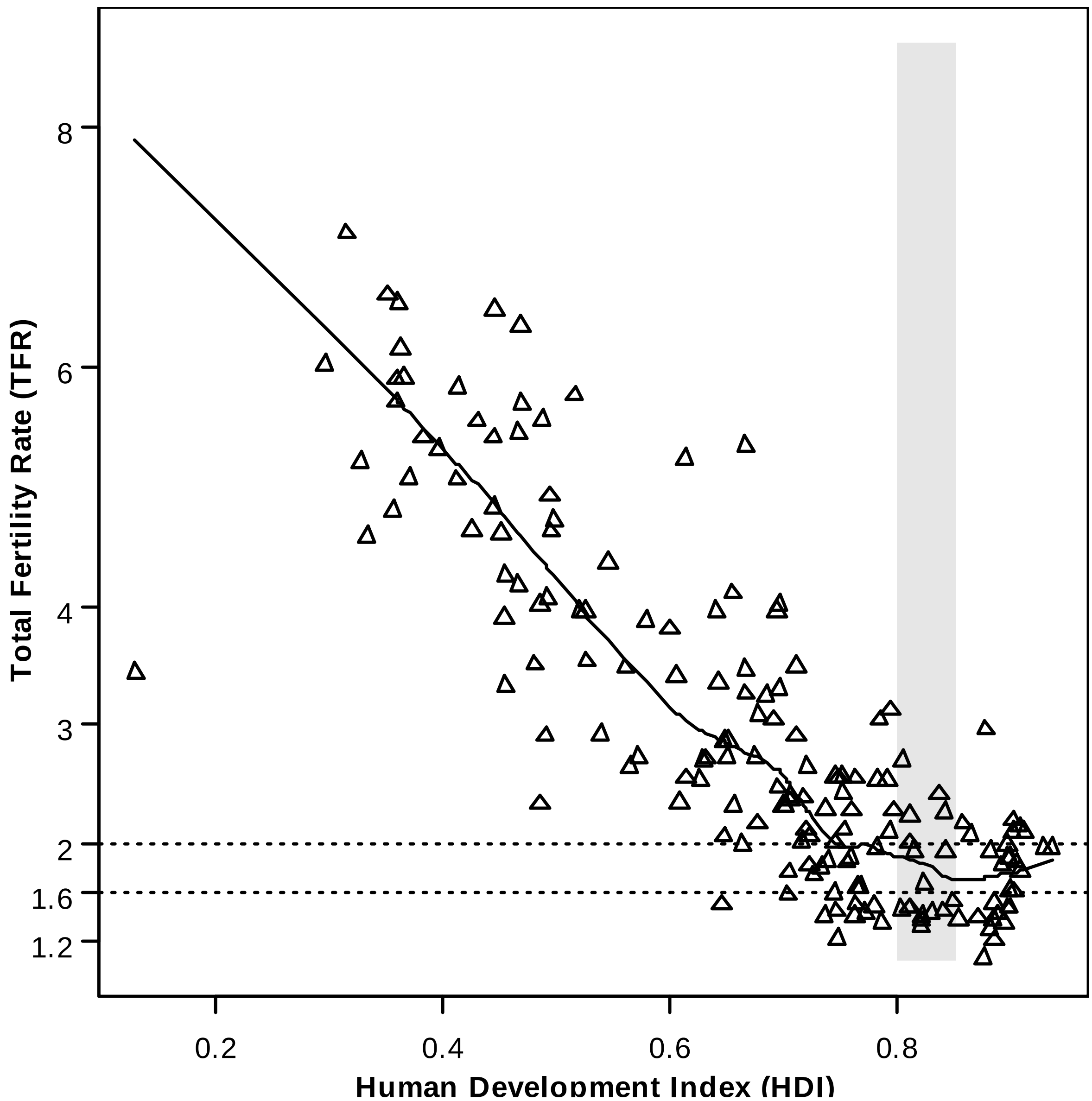
Appendix Table A.1, continued.

	Country	ISO abbrev.	TFR 1975	TFR 2008	HDI 1975	HDI 2008	Completed fertility, 1970 birth cohort	Average Global Gender Gap Index, 2006-2010
86	Thailand	TH	4.49	1.82	0.54	0.72		
87	Tunisia	TN	5.86	2.06	0.47	0.72		
88	Belize	BZ	6.28	2.90	0.57	0.71		
89	Jordan	JO	7.62	3.49	0.55	0.71		
90	Maldives	MV	7.02	2.02		0.71		
91	Suriname	SR	4.74	2.40	0.66	0.71		
92	Algeria	DZ	7.33	2.36	0.48	0.70		
93	China	CN	3.78	1.77	0.39	0.70		
94	El Salvador	SV	5.72	2.32	0.54	0.70		
95	Georgia	GE	2.50	1.58	0.69	0.70		
96	Sri Lanka	LK	3.78	2.33	0.56	0.70		
97	Tonga	TO	5.43	4.00	0.58	0.70		
98	Gabon	GA	5.02	3.31	0.61	0.69		
99	Paraguay	PY	5.22	3.05	0.58	0.69		
100	Samoa	WS	5.24	3.95	0.58	0.69		
101	Turkmenistan	TM	5.78	2.48		0.69		
102	Indonesia	ID	5.04	2.17	0.42	0.68		
103	Philippines	PH	5.75	3.08	0.57	0.68		
104	Syria	SY	7.51	3.25	0.50	0.68		
105	Bolivia	BO	6.18	3.46	0.49	0.67		
106	Equatorial Guinea	GQ	5.67	5.34		0.67		
107	Fiji	FJ	4.05	2.73	0.59	0.67		
108	Honduras	HN	6.84	3.26	0.49	0.67		
109	Mongolia	MN	7.07	2.00	0.53	0.66		
110	Botswana	BW	6.48	2.87	0.46	0.65		
111	Cape Verde	CV	6.93	2.73		0.65		
112	Egypt	EG	5.65	2.86	0.42	0.65		
113	Guatemala	GT	6.20	4.11	0.45	0.65		
114	Guyana	GY	4.38	2.32	0.58	0.65		
115	Vietnam	VN	6.36	2.06	0.40	0.65		
116	Moldova	MD	2.48	1.50	0.61	0.64		
117	Namibia	NA	6.65	3.36		0.64		
118	Vanuatu	VU	5.93	3.96		0.64		
119	Kyrgyzstan	KG	4.87	2.70	0.57	0.63		
120	Nicaragua	NI	6.60	2.72	0.51	0.63		
121	South Africa	ZA	5.25	2.54	0.57	0.63		
122	Morocco	MA	6.42	2.35	0.38	0.61		
123	Uzbekistan	UZ	5.67	2.56	0.57	0.61		
124	Yemen	YE	8.71	5.22		0.61		
125	Sao Tome and Principe	ST	6.54	3.81		0.60		
126	Tajikistan	TJ	6.40	3.41	0.59	0.60		
127	Solomon Islands	SB	7.24	3.87		0.58		
128	India	IN	5.08	2.74	0.36	0.57		
129	Bhutan	BT	6.69	2.64		0.56		
130	Lao	LA	5.98	3.47	0.33	0.56		

Appendix Table A.1, continued.

	Country	ISO abbrev.	TFR 1975	TFR 2008	HDI 1975	HDI 2008	Completed fertility, 1970 birth cohort	Average Global Gender Gap Index, 2006-2010
131	Cambodia	KH	4.93	2.91	0.27	0.54		
132	Congo	CG	6.33	4.37	0.51	0.54		
133	Swaziland	SZ	6.82	3.53	0.47	0.53		
134	Comoros	KM	7.05	3.95		0.52		
135	Pakistan	PK	6.93	3.96	0.33	0.52		
136	Angola	AO	7.19	5.76		0.51		
137	Madagascar	MG	7.22	4.72	0.39	0.50		
138	Cameroon	CM	6.37	4.62	0.40	0.49		
139	Kenya	KE	7.84	4.92	0.43	0.49		
140	Nepal	NP	6.08	2.90	0.24	0.49		
141	Papua New Guinea	PG	6.00	4.07	0.34	0.49		
142	Tanzania	TZ	6.75	5.56		0.49		
143	Bangladesh	BD	6.80	2.34	0.29	0.48		
144	Ghana	GH	6.82	4.00	0.36	0.48		
145	Haiti	HT	5.64	3.50		0.48		
146	Benin	BJ	6.84	5.45	0.28	0.47		
147	Mauritania	MR	6.68	4.47	0.39	0.47		
148	Nigeria	NG	6.82	5.70	0.33	0.47		
149	Sudan	SD	6.57	4.17	0.32	0.47		
150	Uganda	UG	7.10	6.34	0.33	0.47		
151	Côte d'Ivoire	CI	7.92	4.60	0.39	0.45		
152	Djibouti	DJ	6.99	3.90	0.35	0.45		
153	Lesotho	LS	5.76	3.33	0.34	0.45		
154	Togo	TG	7.28	4.26	0.35	0.45		
155	Rwanda	RW	8.23	5.41	0.29	0.44		
156	Senegal	SN	7.56	4.82	0.29	0.44		
157	Timor-Leste	TL	5.15	6.48		0.44		
158	Malawi	MW	7.53	5.55	0.29	0.43		
159	Eritrea	ER	6.50	4.63		0.42		
160	Gambia	GM	6.35	5.05	0.30	0.41		
161	Zambia	ZM	7.44	5.83	0.46	0.41		
162	Ethiopia	ET	6.77	5.32	0.21	0.40		
163	Guinea	GN	6.88	5.41		0.38		
164	Burkina Faso	BF	6.87	5.91	0.18	0.37		
165	Mozambique	MZ	6.55	5.06	0.23	0.37		
166	Central African Rep.	CF	5.95	4.80	0.30	0.36		
167	Chad	TD	6.68	6.16	0.21	0.36		
168	Guinea-Bissau	GW	6.94	5.71	0.20	0.36		
169	Liberia	LR	6.55	5.90	0.31	0.36		
170	Mali	ML	6.71	6.54	0.19	0.36		
171	Afghanistan	AF	7.69	6.60	0.23	0.35		
172	Burundi	BI	6.80	4.59	0.20	0.33		
173	Sierra Leone	SL	5.86	5.20	0.27	0.33		
174	Niger	NE	7.89	7.12	0.16	0.31		
175	Congo	CD	6.37	6.03	0.34	0.30		
176	Zimbabwe	ZW	7.40	3.43	0.29	0.13		

Appendix Figure A.1. Cross-country relationship between Total Fertility Rate (TFR) and Human Development Index (HDI), year 2008: Data points and a lowess curve fitted to the data. The Figure A.1 illustrates that the positive association between TFR and HDI is observed at HDI levels above 0.85 independently of the scaling used in Figure 1.



Notes:
(1) Countries with year 2008 HDI in the range 0.80-0.84 are in alphabetical order: Argentina, Chile, Croatia, Czech Republic, Estonia, Hungary, Latvia, Libya, Lithuania, Malta, Poland, Qatar, Slovakia, Uruguay.

(2) Countries with year 2008 HDI at least 0.85 are in alphabetical order: Australia, Austria, Belgium, Brunei Darussalam, Canada, Denmark, Finland, France, Germany, Greece, Hong Kong, Iceland, Ireland, Israel, Italy, Japan, South Korea, Kuwait, Luxembourg, Netherlands, New Zealand, Norway, Portugal, Singapore, Slovenia, Spain, Sweden, Switzerland, United Kingdom, United States.

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1 Large-scale female labor force participation is a characteristic feature of the post-World War II economic development in most of the contemporary developed countries. The major exceptions include certain countries such as Brunei Darussalam, United Arab Emirates, or Bahrain that are particularly well endowed with natural resources, in particularly with oil. These special features of the national economy have allowed the resource-rich countries to attain high levels of economic development without large increase in female labor force participation.

2 The period fertility rates reflect the number of children that would be born to a woman during the specified age window if she experienced the age-specific fertility rates observed in a calendar year. The literature has illustrated weaknesses in these period measures (Bongaarts and Feeney 1998; Sobotka and Lutz 2009). There are, however, several reasons for using the TFR in fertility analysis. First, the main critique against the TFR is that it is subject to tempo effects of fertility. We acknowledge the critique, and back the TFR analyses with cohort fertility analyses and adjustments for the timing of fertility. Second, data availability often governs what can be done, and that is true also for our study. The TFR is the only behavioral measure of fertility available for a large number of countries and for many years, and it is the only fertility measure for which longitudinal large-scale analyses on the association between development and fertility are feasible. Third, TFR remains the most widely used indicator of fertility, as TFR is a key determinant of the number of children born in a calendar year, and thus of population ageing and population growth/decline. Finally, most policy debates about fertility trends focus on the TFR (Balter 2006).

3 In the longitudinal regressions of TFR on HDI we use data on 35 countries and the mean age at birth (MAB) as a covariate to adjust for changes in the timing of fertility (see the section Results for details). Using MAB as a covariate is an alternative to using tempo-adjusted TFR as the dependent variable, and the choice between the two is mainly dictated by data availability: for the 35 countries, longitudinal time-series of tempo-adjusted TFR starting from 1975, or the parity-specific data required to calculate the tempo-adjusted TFR, are not available. The mean age at first birth could also be considered as an alternative to MAB as a regression covariate. However, mean age at first birth is also not available for the 35 countries we analyze in the longitudinal regressions. Therefore we use MAB, which depends on the timing of births, but also on the parity distribution of births. Changing parity distribution of births adds noise to the measure and makes the MAB a non-optimal indicator for tempo-adjustment. However, given the available data, MAB is the best possible indicator for adjusting for the changes in the timing of fertility. As a crude check for the validity of MAB in capturing the influence of changing fertility timing on TFR we regressed the TFR on quadratic MAB using longitudinal data for all the 35 countries and controlled for year and country fixed effects. If the MAB captured the influence of changes in the timing of fertility on the TFR, the relationship between the TFR and MAB should follow an inverted U-shape pattern: TFR first decreases when MAB starts increasing, but when increase in MAB slows down the suppressing effect should weaken and TFR should increase. This was the observed pattern: net of country- and year effects, TFR decreased with respect to MAB up to MAB 25, and then started increasing, being 0.20 higher at MAB 28 than 25.

4 For example, the education index changed from literacy and enrollment rate based index to years of schooling based index, and the income index which was based on GDP per capita is in the 2011 revision based on per capita gross national income.

5 This index, which UNDP terms the hybrid-HDI but for shortness we call HDI, is calculated as the geometric mean of scaled life expectancy, education, and income indexes LE, EI, II as (LE*EI*II)^1/3, where the sub-indexes are obtained as LE = (e0-20)/(83.166-20) and e0 is the period life expectancy at

birth; EI = (LIT*GER)^1/2, where LIT=(Lit-0)/(99-0) and Lit is the adult literacy rate and GER=(Ger-0)/(115.8192-0) and Ger is the combined (primary, secondary, tertiary) gross enrollment ratio; and II = (ln(GDP)-ln(163.28143)/(ln(106769.74)-ln(163.28143) where GDP is the gross domestic product per capita at purchasing power parity, 2000 US $.

6 Regression of the time-consistent HDI on the earlier, arithmetic means based HDI (HDIa) for the year 2005 is HDI = -.044 + 0.975*HDIa (with R^2 0.994), implying a .06 unit lower value for the time-consistent HDI than for HDIa at HDIa level 0.80.

7 Alternatives to the Global Gender Gap index, such as the UNDP's Gender-related Development Index (GDI) or the Gender Empowerment Measure (GEM) could also be considered (Mills 2010). The GDI measures achievement in the same basic capabilities as the HDI does, but imposes a penalty for inequality, such that the GDI falls when the disparity between men's and women's achievement levels increases. Thus GDI is simply the HDI discounted, or adjusted downwards, for gender inequality. This might explain why Mills (2010) finds it is the index with the strongest correlation with fertility intentions. The GEM, in turn, evaluates progress in advancing women's standing in political and economic forums. It examines the extent to which women and men are able to actively participate in economic and political life and take part in decision-making. While the GDI focuses on expansion of capabilities, the GEM is concerned with the use of those capabilities. We prefer the GGG over the alternatives GDI and GEM for three reasons. First, the GGG measures gender equality independently of the level of development, and may score high in contexts where men and women are equally deprived. This is not the case for the Gender-related Development Index GDI, which measures achievement in the same basic capabilities as the HDI does, but imposes a penalty for the male-female difference. Second, the economic and political equality components of GGG capture the dimensions of the Gender Empowerment Measure GEM. Therefore the information in GEM would not add much over the components of GGG. Third, we estimated the associations using the abovementioned alternative gender equality measures; the results were qualitatively similar.

8 We use the years 1985 and 2005 because for many countries age-specific fertility data not available for the endpoints of this study, years 1975 and 2008.

9 The results of Figure 3 are consistent with those presented in Myrskylä et al. (2009). Of the countries that Myrskylä et al. (2009) identified as having a positive HDI-TFR trajectory at high HDI levels all have such positive TFR-HDI trajectory also in Figure 3. Myrskylä et al. (2009) identified 6 countries as having a negative HDI-TFR trajectory at high levels of development (Austria, Australia, Switzerland, Canada, South Korea and Japan). Figure 3 includes 8 countries that have such a negative HDI-TFR trajectory at high levels of development (Austria, Switzerland, Canada, Japan, South Korea, Brunei, Kuwait and Singapore). Of these, Brunei, Kuwait and Singapore are new compared to the set of countries analyzed by Myrskylä et al. (2009). Of the countries that Myrskylä et al. (2009) identified as having a negative HDI-TFR trajectory at high HDI levels, all except one (Australia) have such a negative trajectory also in Figure 3. Australia, however, was only borderline negative already in Myrskylä et al. (2009).

10 We use the median instead of the mean because the latter is sensitive to outliers, such as Brunei. Also the mean of the trajectories, however, is positive after the reference year (average slope of TFR with respect to HDI 1.4) and indicates a positive relationship between TFR and HDI at high levels of development. For the sensitivity of the mean to outliers we use the median also when summarizing the age-specific fertility trajectories in Figure 4.

11 Longitudinal data on age-specific fertility is not widely available. Therefore the number of countries in these age-specific analyses drops from 30 in Figure 3 to 25 in Figure 4. The excluded five countries are Kuwait, Singapore, Brunei, Israel, and Hong Kong. Figure 3 shows that of these excluded countries, three (Kuwait, Brunei, Singapore) had the fastest fertility decline with respect to development at HDI levels above 0.85. Thus it is possible that the group of excluded countries would show deviating trends also in the age-specific fertility if there was data to study that. Therefore the conclusions drawn from Figure 4 should not be extrapolated to Middle-Eastern countries as no data points are available from there. Of East Asian countries only South Korea and Japan are present in Figure 4, thus conclusions regarding this region are also tentative. The evidence is stronger for European and English-speaking countries.

12 As a sensitivity check, we estimated the regression models 1-2 also with random instead of fixed country effects, and with differenced data instead of using data in levels. The results were consistent with the fixed effects specification.

13 In the paper “Advances in Development Reverse Fertility Declines” we used a structural break model to estimate the HDI-TFR relationship. The model allowed the HDI coefficient to change at a level that was estimated from the data. Here we update the models in order to respond to the critique that the modeling strategy received. First, some have suggested that the structural break technique does not provide an all-in-one estimation of the level at which the HDI-TFR relationship changes (Luci and Thevenon 2010). The critique is not entirely accurate as the break was estimated from the data (resulting in two-step estimation). Nevertheless, we have revised the model to be a one-step quadratic model. The quadratic model may be more realistic as it allows for a smooth change. Second, some have suggested that our results were driven by inclusion of low-HDI data points (Lauer 2009). In order to guard against this possibility, we have revised the regressions in two ways. First, we use only data that pertain to HDI levels 0.75 and above, excluding all countries that are categorized low- or medium-development (UNDP 2011). Second, we estimate regression models with country-specific time trends. When the time trend is not be estimation design forced to be shared, the time trend of any low, middle, or high development country can not drive the estimated coefficient for HDI.

14 The regression models 1-4 have a parsimonious quadratic specification which allows documenting that there is a reversal in the TFR-HDI association from negative to positive at HDI range 0.80-0.85. However the quadratic specification may also result in unrealistic predictions particularly at very high levels of HDI. For example, the quadratic specification implies that after the reversal in the HDI-TFR from negative to positive, the positive effect of HDI on TFR increases with increasing HDI to potentially unrealistic levels at HDI levels above 0.90. An alternative, more flexible but less parsimonious specification for the HDI-TFR association is qubic, which allows for two turning points in the TFR-HDI association within the observed HDI range. We estimated the Models 1-4 with qubic instead of the quadratic specification and each of these models suggested that the TFR-HDI association changes from negative to positive in the HDI range 0.80-0.85, and at very high HDI levels (0.90-0.95) the positive association flattens. For example, for the Model 1 with quadratic specification the predicted change in TFR for HDI change from 0.825 to 0.875 is +0.21 ($p<.05$). At higher HDI levels the association levels off, and for the HDI change from 0.875 to 0.95 the predicted change in TFR is a +.02 ($p=.94$).